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ON VEHICULAR COMMUNICATIONS

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TRANSISTORIZED MICROPHONES FOR VEHICULAR COMMUNICATIONS

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Shure Brothers, Incorporated
Evanston, Illinois

Summary

With the emphasis on intelligibility and reliability, the use of carbon microphones in vehicular communications is rapidly diminishing. Instead, magnetic and dynamic microphones with built-in transistor preamplifiers have been gaining considerable favor. For existing equipment, the amplifier draws its power from the carbon microphone circuit so that, in most cases, equipment changes are not required. Among the interesting possibilities in new equipment is a talk-back provision, whereby the microphone also acts as a speaker. Circuit considerations, environmental stability, and performance will be treated.

Introduction

The increasing use of vehicular communications has resulted in overcrowding of the radio frequency bands allocated for this purpose, placing a much greater emphasis on intelligibility, which is reflected in an overall need for improved quality of transmission. The communication system consists of several links, having equally important roles in bringing about this improvement. One major link in this system is the microphone. In spite of its importance, normal usage precludes protective isolation and the microphone frequently must operate under adverse conditions which impose great demands on its durability and stability. Carbon microphones, long used for vehicular communications, have served well because of their high sensitivity. There are inherent limitations in the carbon microphone however, such that it does not lend itself well to resolving the problem of improved transmission quality.

Magnetic Microphone

One solution is obtained by the use of a balanced armature magnetic microphone. This type of transducer is characterized by high sensitivity (for a self-generating transducer), good response-frequency characteristic for voice communication, a wide choice of internal impedances and excellent physical characteristics. A properly designed transducer is independent of extremes in temperature or humidity and will be substantially unaffected by severe mechanical vibration.

Figure 1 shows the response-frequency characteristic of a typical controlled magnetic microphone. The variation of open circuit voltage as a function of cartridge internal impedance for currently available impedances is shown at the top of Figure 1. The table gives the 1000 cps output in db relative to one volt for a one hundred microbar sound field, which is approximately the sound pressure at the face of a close talking microphone in normal use. Although it has many excellent characteristics, the lower sensitivity of the magnetic microphone requires careful cable shielding in order to minimize electrical interference.

Transistor Amplifier

If it were practicable to place a small amplifier into the microphone housing without introducing circuit complexities that affect the reliability of the microphone, the cable shielding and interference problems could be minimized. With the advent of the transistor, it has become possible to make very small amplifiers which can be incorporated in the microphone housing.

Figure 2 shows a transistor amplifier designed for this purpose. On the right is a potted version equivalent to the printed circuit plates shown on the left.

The amplifier is a single stage device utilizing a PNP transistor in a common emitter configuration. This is shown in Figure 3. Stabilizing circuitry is employed to minimize parameter variations that occur with temperature changes. Temperature stability unquestionably is one of the most important requirements for a component being used for vehicular communications.

Figure 4 shows the frequency response variations of the amplifier for various temperatures. The 1000 cycle response variation is within 4 db for a temperature range of $+150^{\circ}F$ to $-42^{\circ}F$. There is another important environmental requirement that must be met-- that is, stability under conditions of high humidity. A relative humidity of 95% at $120^{\circ}F$ for 100 hours showed no noticeable change in the characteristics of the amplifier.

Having a stable amplifier stage provides the necessary link between the microphone cartridge and the transmitter input circuit to more fully utilize the magnetic microphone's desirable characteristics.

Transistorized Microphone

The 505T Transistorized microphone has been developed to permit the magnetic microphone to approximate the high sensitivity of a carbon microphone with none of its inherent limitations. In many cases, the transistorized microphone can serve as a direct replacement for carbon microphones without change in the transmitter.

OPEN CIRCUIT OUTPUT OF CONTROLLED MAGNETIC MICROPHONE.
100 MICROBARS ACOUSTIC INPUT.

INTERNAL IMPEDANCE OHMS	1 KC. OPEN CKT. OUTPUT db re 1 VOLT
50	-37
200	-31
1,500	-22
4,000	-18
15,000	-12

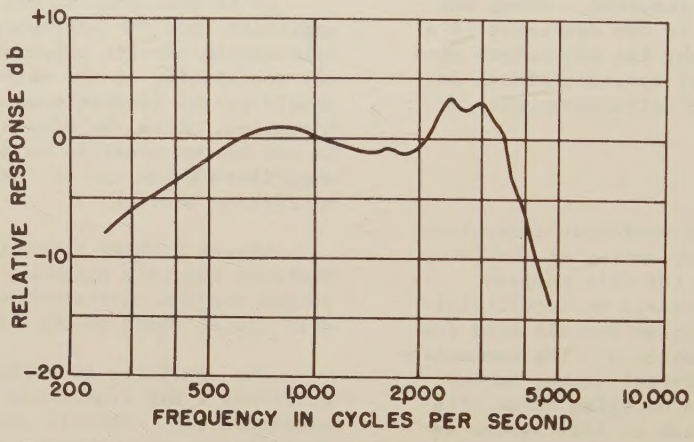

Fig. 1 - Controlled magnetic microphone characteristics.

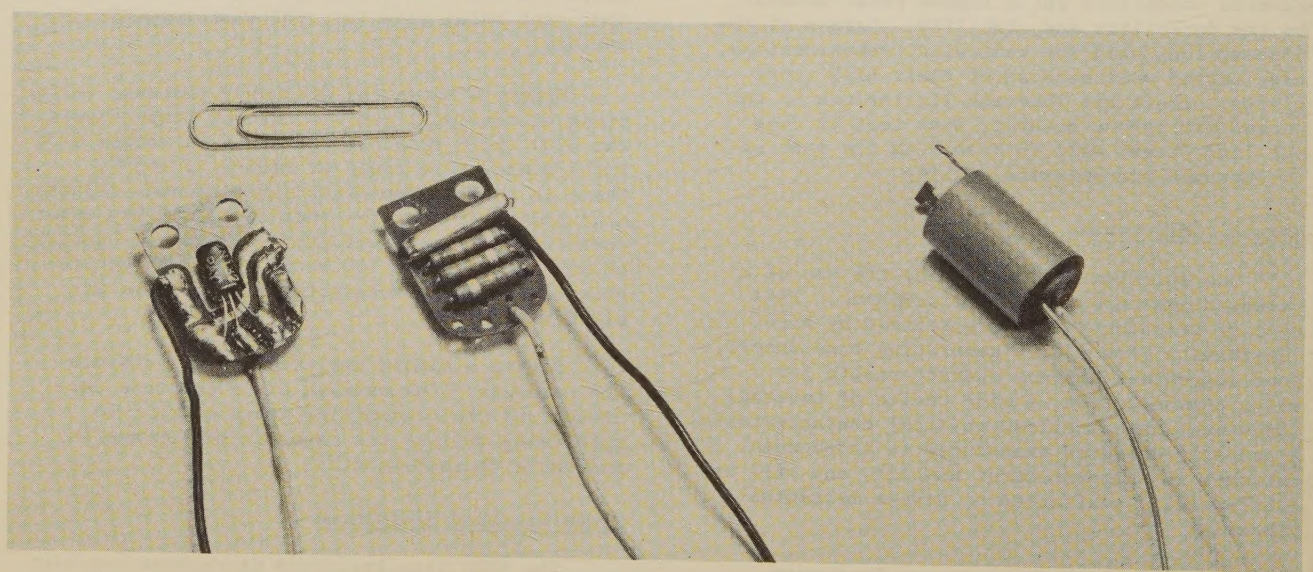

Fig. 2 - Transistor amplifiers.

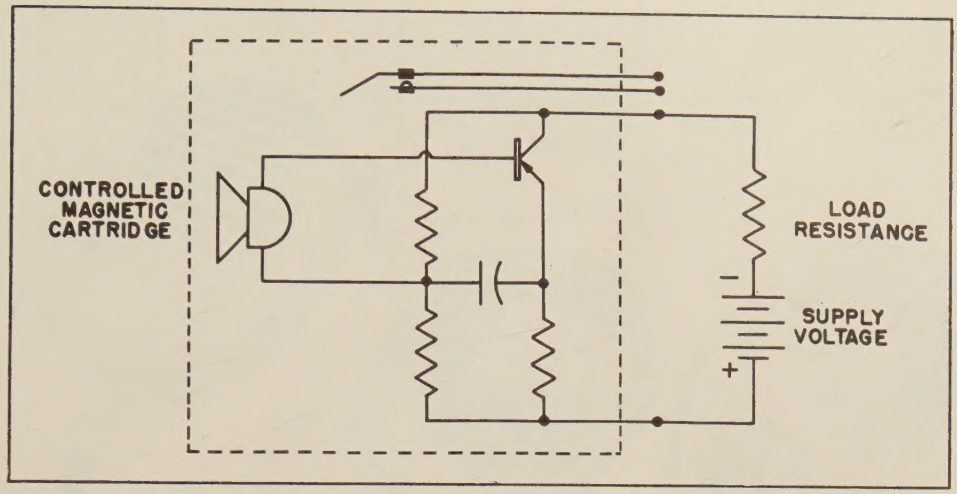

Fig. 3 - Circuit diagram of transistorized microphone.

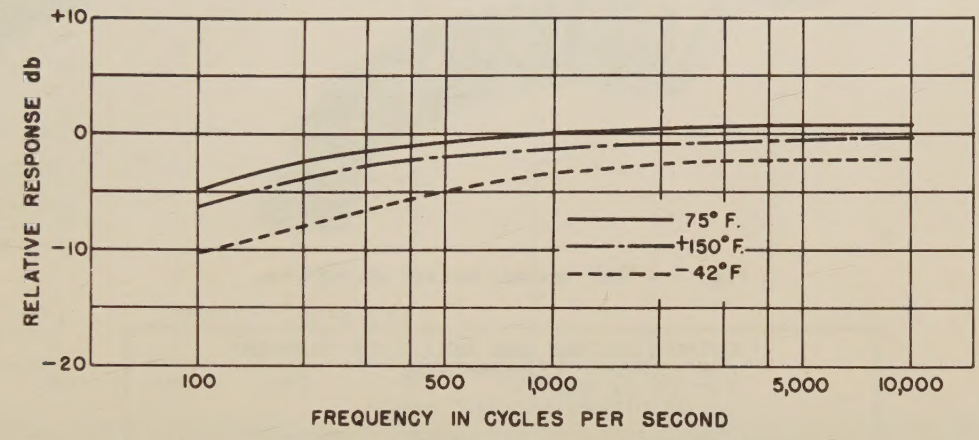

Fig. 4 - Temperature effects on transistor amplifier.

Figure 5 shows the internal construction of the 505T. A heavy duty leaf spring switch is incorporated to allow control of external circuits. The transistor amplifier is held in position by the screws which also mount the switch.

To properly use the transistorized microphone, whether in existing or new equipment, one must evaluate the operational changes that occur in the microphone when combinations of various load resistances and voltages are used.

The relative frequency response of the complete transistorized microphone is shown in Figure 6. The table was prepared to indicate 1 kc output voltage and the collector current for various load resistances using a 6 Volt D.C. supply. The change in shape of the curve for changes in load resistance is negligible.

Figure 7 shows the output voltage as a function of input voltage for various supply voltages with a fixed load resistance of 500 ohms. The dotted vertical line indicates the value of input voltage equivalent to that obtained from a 100 microbar signal applied to the microphone. As the supply voltage is decreased, the distortion increases for a given sound field and load resistance.

From Figures 6 and 7 it is apparent that the operating parameters of the transistorized microphone are dependent on the particular values of load resistance and supply voltage. However, it is possible to choose a set of conditions that will yield optimum results for a wide variety of applications. Under optimum operating conditions the signal to noise ratio of the amplifier was found to be more than 60 db below an equivalent 100 microbar acoustic signal.

Dual Transducer

In some applications it is possible to achieve a certain degree of simplicity by using the same transducer as a microphone and as a speaker. Figure 8 shows three elements commonly used for vehicular communications. On the left is a carbon microphone element, in the center the balanced armature magnetic, and on the right a

Fig. 5 - 505T transistorized microphone.

OUTPUT VOLTAGE AND COLLECTOR CURRENT
FOR VARIOUS TERMINATIONS.
6 VOLTS D.C. SUPPLY.
100 MICROBARS ACOUSTIC INPUT

TERMINATION RESISTANCE RL OHMS	COLLECTOR CURRENT MA.	1 KC. OUTPUT db re 1 VOLT
50	3.8	-24
100	3.6	-18
200	3.4	-12
500	2.8	-4
1,000	2.6	0

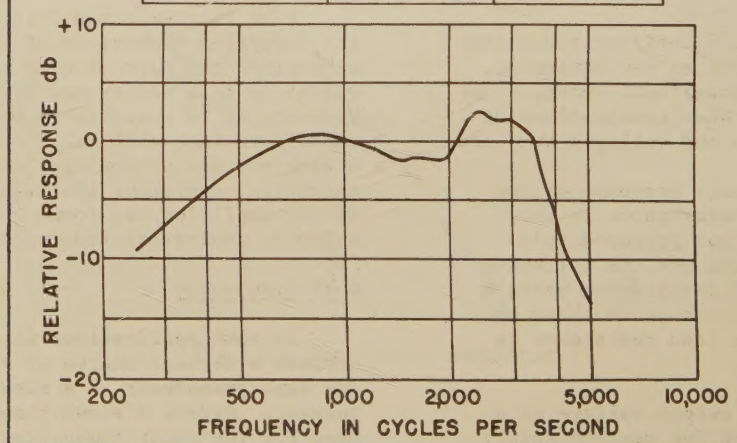

Fig. 6 - 505T transistorized microphone characteristics.

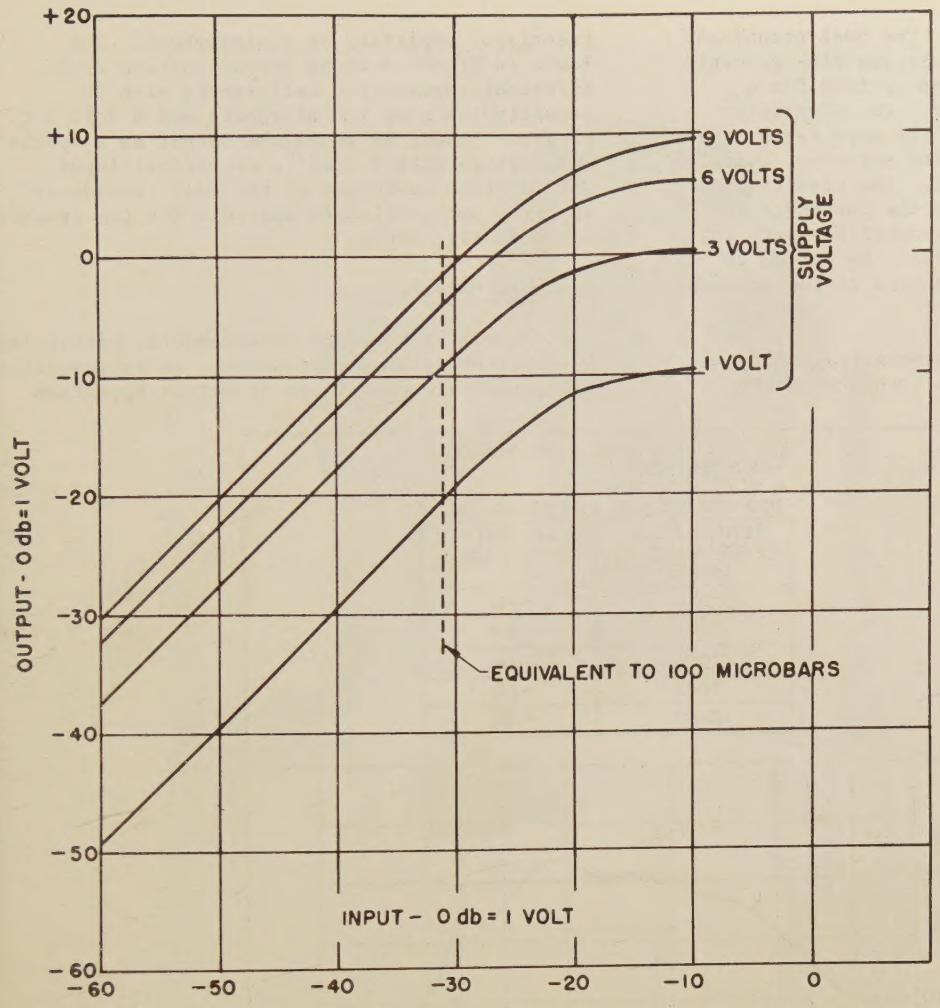

Fig. 7 - Transistorized amplifier, relationship between input and output for various supply voltages. Source resistance is 200 ohms and load resistance is 500 ohms.

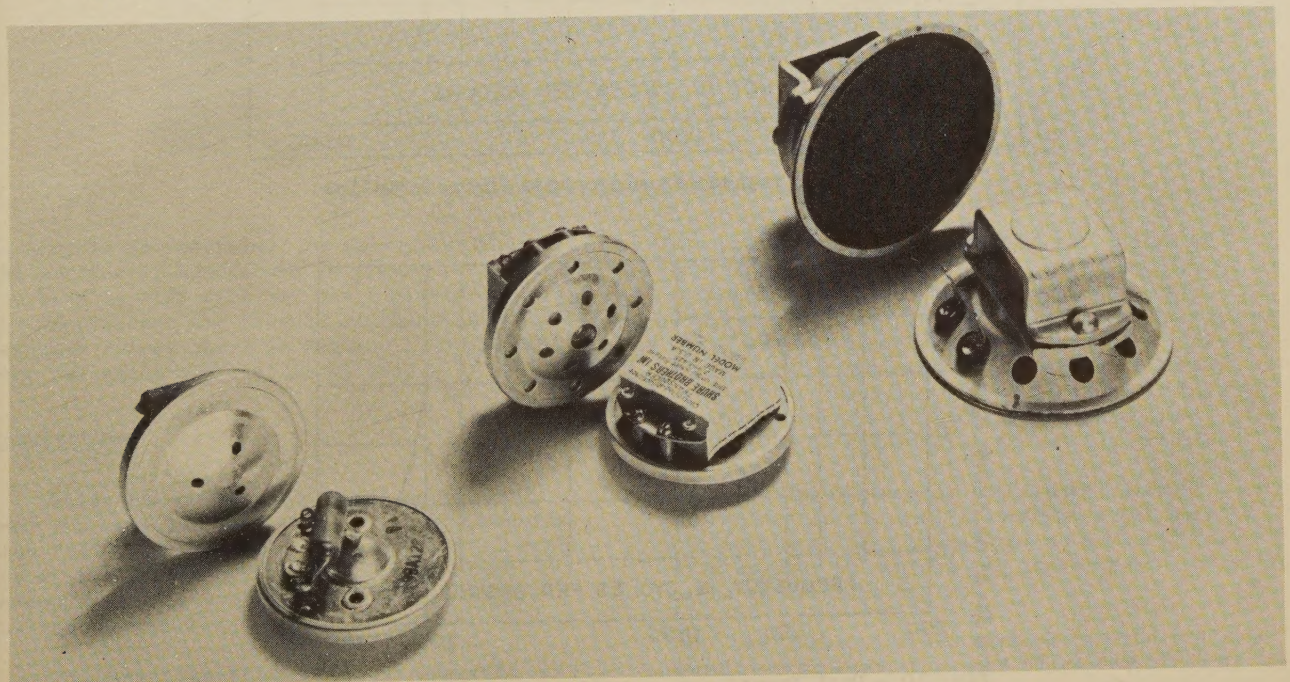

Fig. 8 - Microphone cartridges: (left) carbon, (center) controlled magnetic and (right) dual transducer.

dual transducer cartridge. The dual transducer is a heavy duty dynamic cartridge with acoustic damping intermediate between optimum for a microphone or a loudspeaker. The simplicity is achieved by eliminating the need for a separate loudspeaker with its attendant installation problems and cabling. The electrical circuit is arranged so that the cartridge is connected to the transistor amplifier with the switch button depressed. When the button is released, there is direct access to the terminals for loudspeaker operation.

Figure 9 gives the response-frequency characteristics of the dual transducer with transistor amplifier as a microphone. The Table in Figure 9 shows output voltage with different termination resistances with an acoustic input of 100 microbars and 6 Volt D.C. supply. Figure 10 shows the output as a speaker when driven with 0.2 watts electrical input. The internal impedance of the dual transducer is fifty ohms, which is suitable for the transistor amplifier input.

Acoustic Measurements

In making acoustic measurements, particularly on close talking microphones, it is essential to approximate conditions of actual operation

OUTPUT VOLTAGE FOR VARIOUS TERMINATIONS.
6 VOLT D.C. SUPPLY
100 MICROBARS ACOUSTIC INPUT.

TERMINATION RESISTANCE R_L OHMS	1 KC OUTPUT db re 1 VOLT
50	-30
100	-24
200	-18
500	-10
1,000	- 6

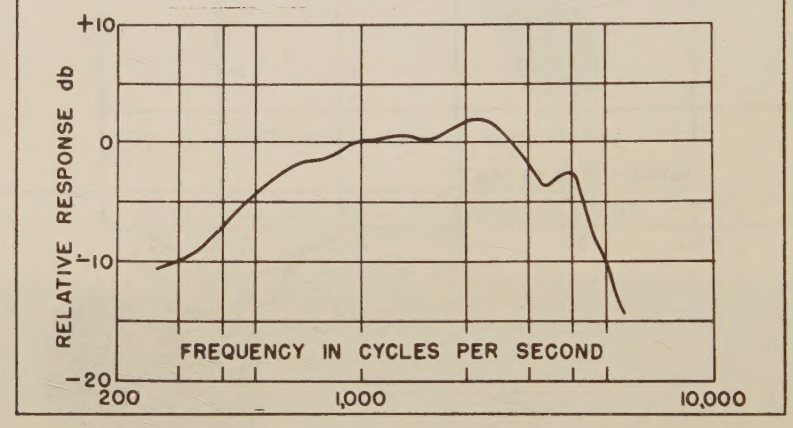

Fig. 9 - Dual transducer microphone characteristics.

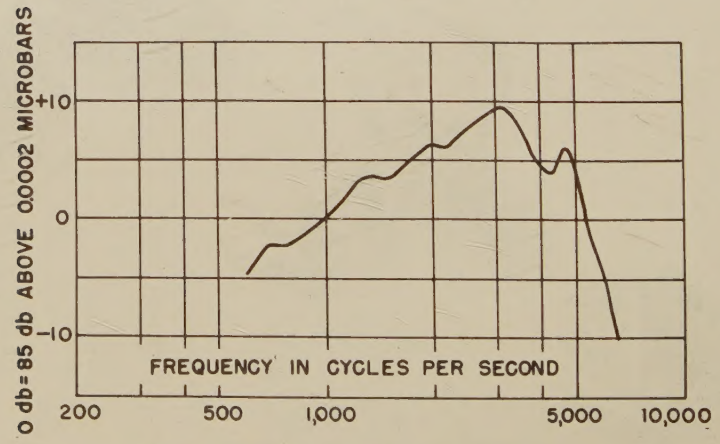

Fig. 10 - Dual transducer acoustic output measured with 12 inches with 0.2 watts electrical input.

Fig. 11 - Artificial head for acoustic measurements.

as closely as possible. To accomplish this, the artificial head shown in Figure 11 is used. The head is life size and has a plastic covering that approaches the texture of the skin. The response curves shown in Figures 1, 6 and 10 were run using the artificial head.

Conclusions

While the carbon microphone has served well for many years in the vehicular communication field, the stringent requirements on quality of transmission that confront us today necessitates the consideration of new higher quality microphones.

The lower sensitivity of the magnetic cartridges compared to the carbon cartridges has been overcome by the introduction of the transistor which has permitted the design of amplifiers small enough to be contained in the microphone housing. This brought about the development of the 505T Transistorized Microphone which can serve in many cases as a direct replacement for the carbon microphone with no transmitter changes. The temperature stability of the microphone is excellent over a wide range, which is essential for mobile systems.

Another version of the transistorized microphone is the dual transducer which permits the same cartridge to be used as a microphone or a speaker by controlling its operation from the press to transmit button.

The transistorized microphone with its high sensitivity, stability, and overall quality is destined to become a very important part of the vehicular communication system of tomorrow.

NEW TYPE HIGH GAIN STATION ANTENNA

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Chicago, Illinois

Summary

There is an ever increasing demand for higher gain in omnidirectional fixed station antennas. A major factor in the pyramiding cost of these structures is the complexity of the feed system. Single feed point systems used in the past have had the disadvantage of low coupling between the driven element and the remotely located elements, resulting in highly tapered illumination and consequently lowered gain.

A new principle for a radiating array has been developed which uses only one feed point but with improved aperture illumination. New elements called "suppressors" isolate the effective portions of the radiating conductor without a need for direct excitation. Results with a unit having 10 db gain at 460 MC are described.

Development

In the past, high gain vertically polarized antennas have consisted of arrays of simple radiating elements. Feeds have been relatively complex harness arrangements. This has been necessary in order to excite each element properly. [1,2, 3, 4, 5, 6].

One aspect in the design of these antennas which is receiving much attention recently is the successful reduction in number of feed points. This is because of its beneficial effect on the weight and cost. Attempts to solve the problem cover a wide span of years. [7,8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]. The Franklin Array [21] is one of the oldest systems which fits into this category. This array is shown diagramatically in Figure 1. A series of end-to-end radiators are connected by phase inverting sections. In the simplest forms, these phasing sections are half wavelength conductors bent into narrow "U" shapes. Thus the entire conducting system is a long wire with special non-radiating portions positioned at right angles to the main portions which radiate in the desired manner.

In the manner shown above, Franklin has eliminated radiation from alternate sections of the conductor, which in the continuous straight length would cancel the radiation from an equal number of the useful sections. There is an implied assumption in this arrangement which we find is not satisfied. This assumption is that the current in the adjacent useful sections is the same, i.e., that there is little or no attenuation of current along the array. A practical way to determine that there is serious attenuation is to study the E-plane pattern as such an array is varied in length. Figures 2 and 3 show the patterns for four-inverter and six-inverter arrays. Note that the main beam for the six-inverter array is only slightly narrower than the main beam for the four-inverter array. This indicates that the endmost sections in the six-inverter array contribute very little to the radiation from the whole array, i.e., there is relatively little current in the endmost sections.

A rough check on the current distribution of the six-inverter array was made by measuring the field intensity along a line close to and parallel with the array sections. This revealed a linear drop in current from section to section of 5 db, or a value of 10 db per

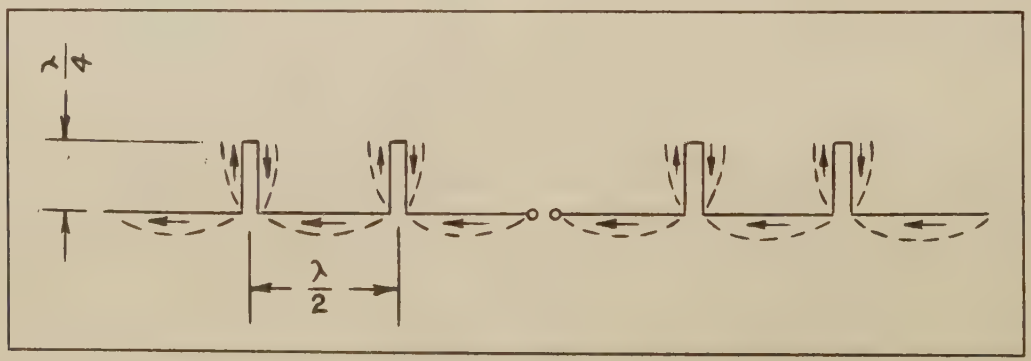

Fig. 1 - Franklin antenna. Arrows indicate instantaneous current directions.

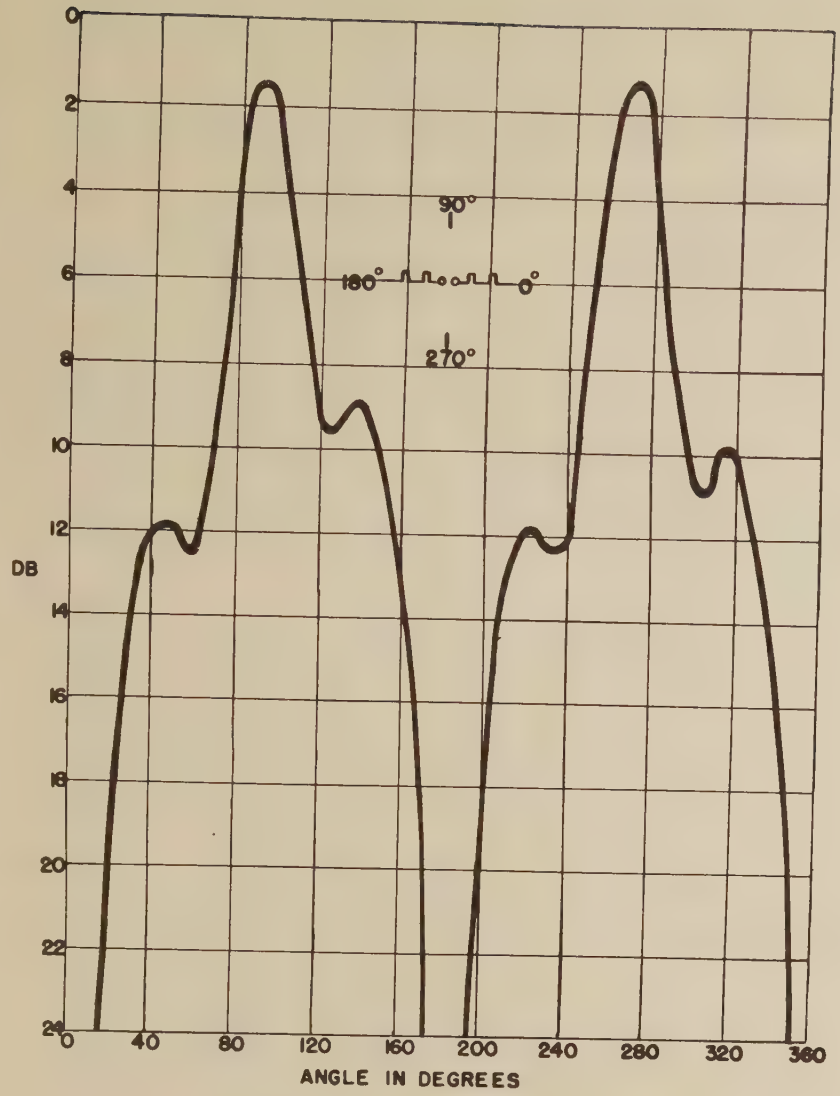

Fig. 2 - E plane pattern, four-inverter Franklin.

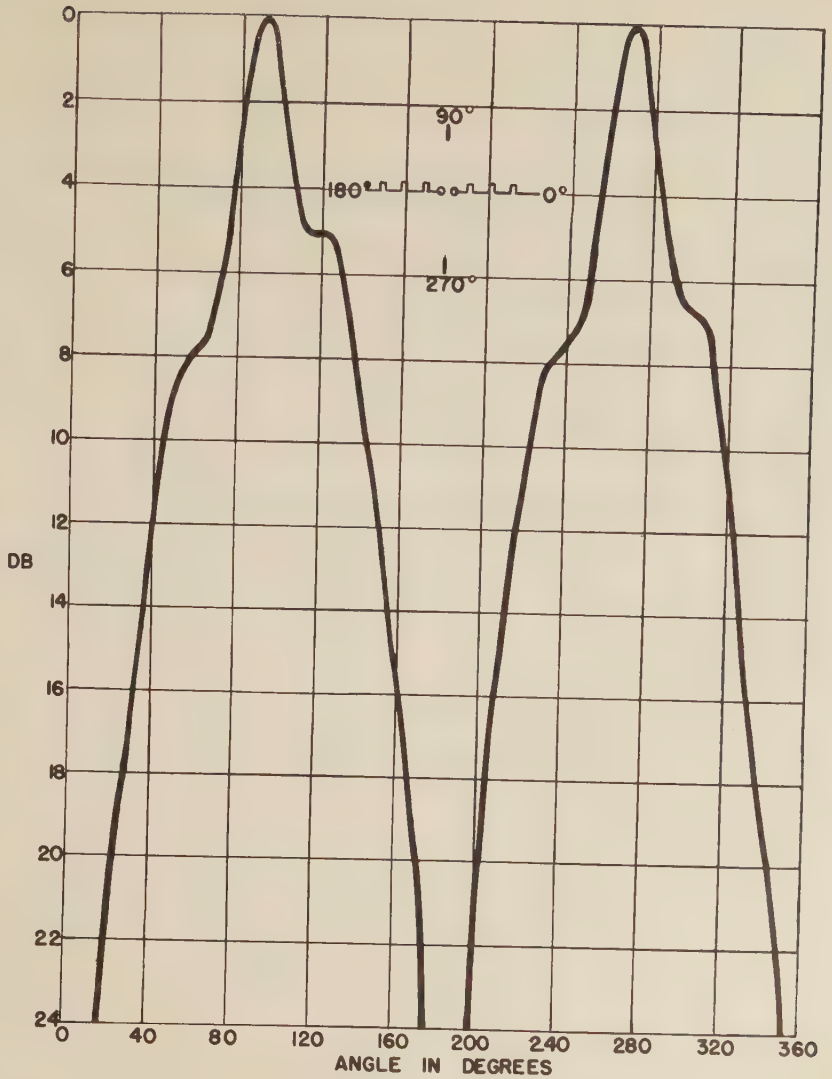

Fig. 3 - E plane pattern, six-inverter Franklin.

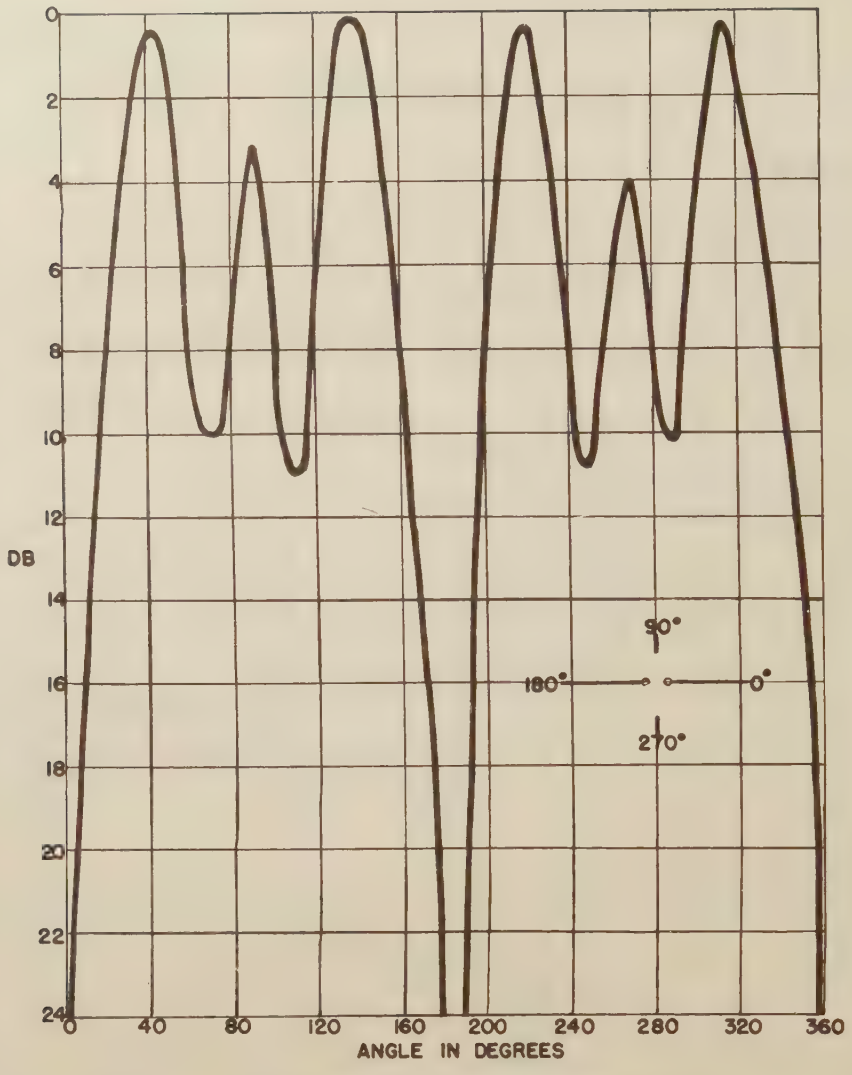

Fig. 4 - E plane pattern, three-wavelength radiator.

wavelength. This measured value will be compared later with a similar value for the new type array.

In planning for the new type array, we conceived the principal of providing a simple straight conductor and "blocking off" the radiation from the interfering alternate sections by some form of shielding unit. A series of successive patterns will show how the final form was developed. Figure 4 shows the pattern for a three-wavelength linear antenna which demonstrates relatively low radiation normal to the antenna conductors with wide and strong sidelobes.

Figure 5 shows the very small change secured by adding some cylindrical members midway at each conductor, in an attempt to provide two half wave radiators, properly excited, at each antenna arm. The results indicate that the current flowing down the main conductors is not forced to flow under the shielding cylinders as intended.

Therefore, it becomes obvious that we must provide some means of eliminating the current flowing over the outside surface of the added cylindrical members. The addition of two cooperative chokes mounted over the cylinders provided this feature as indicated in Figure 6. Each of the elements which is used to eliminate the undesirable radiation has a cross section as indicated in Figure 7. We call them suppressors* because of their behavior.

A further check on the action of the suppressor elements is to study the current distribution. Current distribution is measured roughly by running a

*Patents applied for

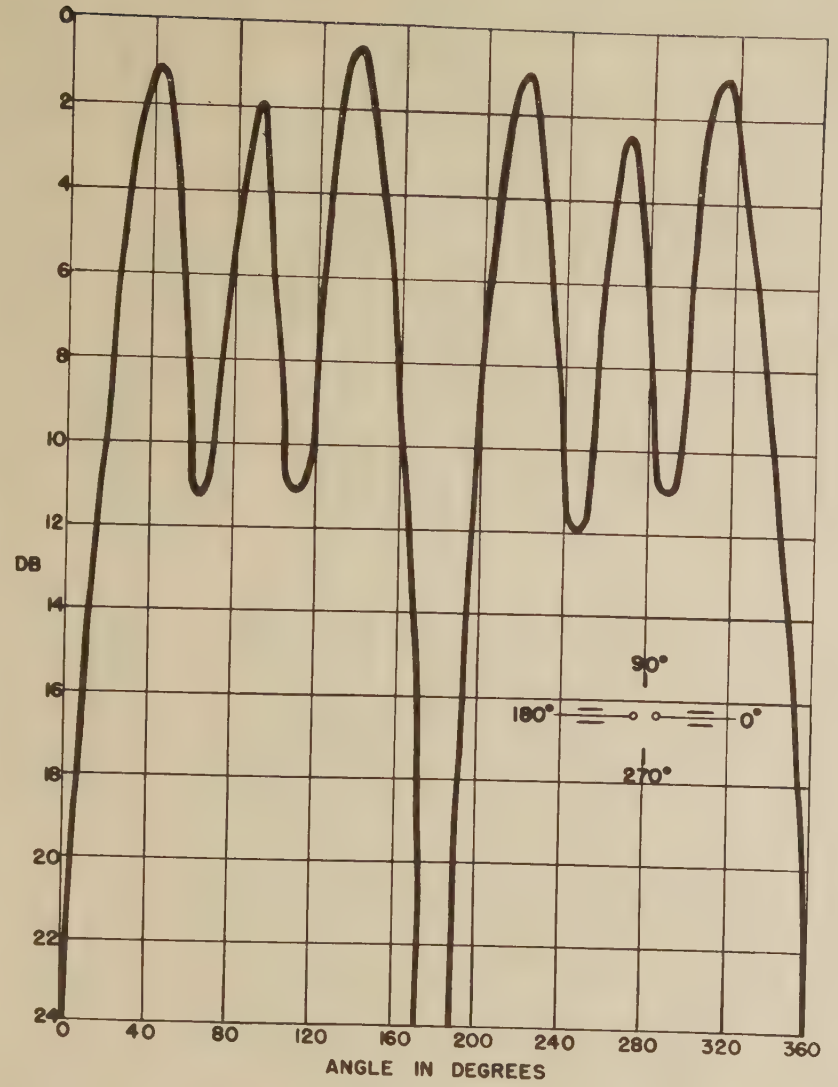

Fig. 5 - E plane pattern, three-wavelength radiator with sleeves.

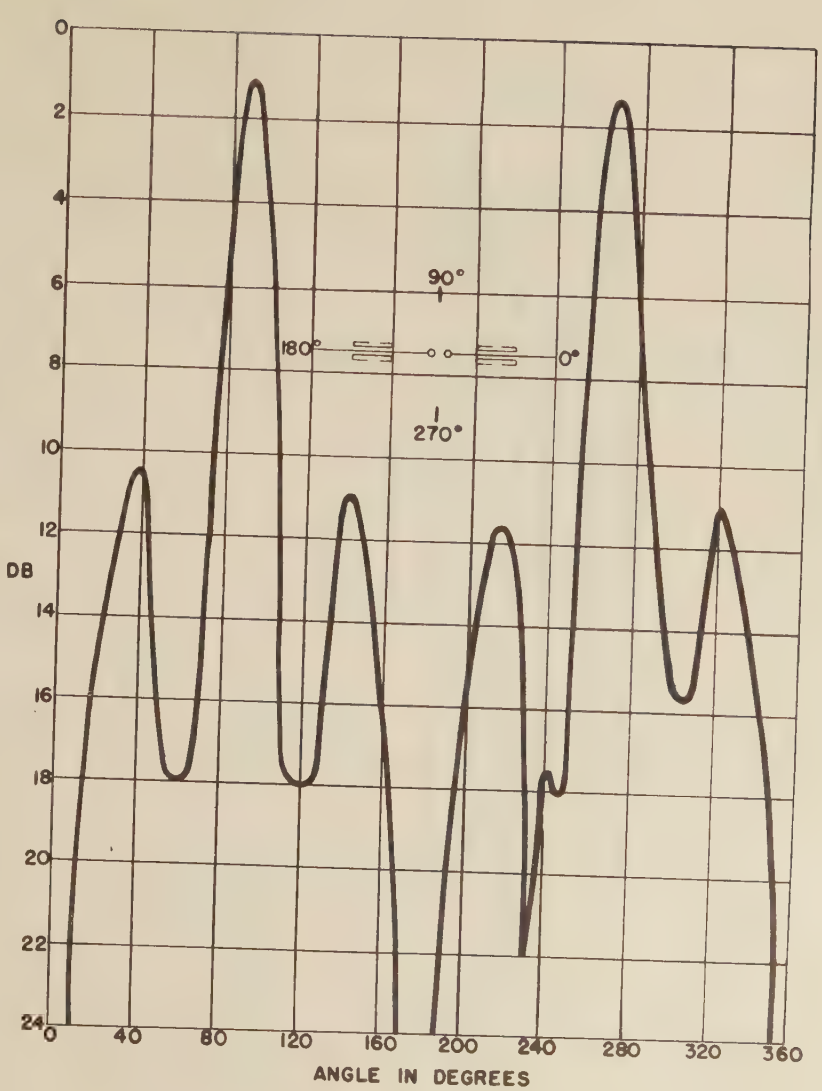

Fig. 6 - E plane pattern, two-suppressor array.

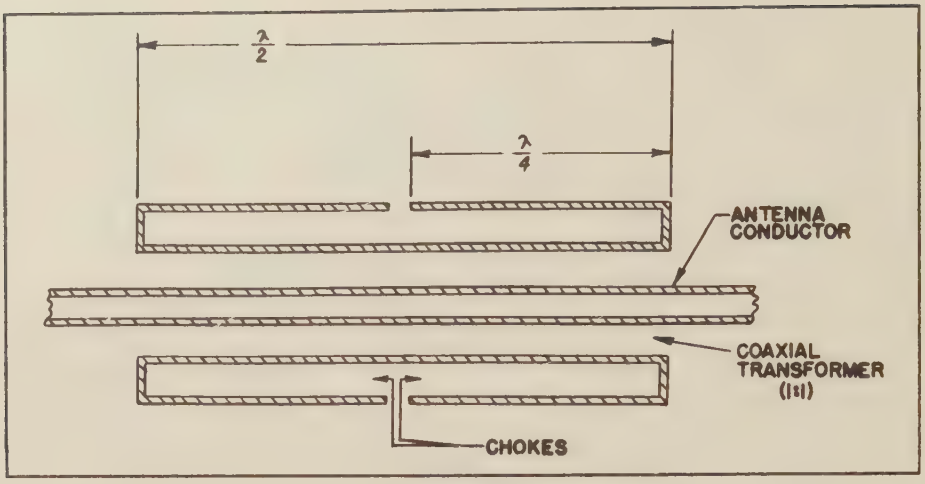

Fig. 7 - Suppressor cross section.

probe along the elements parallel to the axis and in close proximity to the surface. Figure 8 shows the current distribution of the simple antenna conductors (shown in Figure 4). This corresponds to what one would expect to obtain, except that some unbalance in the feed system has resulted in unequal excitation of the two halves of the antenna.

Figure 9 shows the current distribution for the antenna fitted with suppressors (shown in Figure 6). This shows satisfactory elimination of the destructive currents such as we had hoped to achieve.

Commercial Antenna

The Andrew type 212 antenna uses this principle to obtain a gain of 10 db at 460 MC, with only one set of feed points. The active radiating portion is 20 feet long, to which must be added the support pipe length of 3 feet. Since an antenna this long is hard to handle in the field and is almost impossible to hoist in building elevators and other confined spaces, it was sectionalized.

Another arbitrary choice was made. This was to split the antenna above the feed point so that the feed cable would remain intact for shipment. Under the above conditions we arrived at a minimum suppressor complement of nine units, four in the lower section and five in the upper section. The structure was separated into three pieces, the longest of which is 12 feet.

In order to establish a heavy conducting path from the top of the antenna to the supporting tubular base member for lightning protection, a special cable coupling system was necessary. This system is incorporated in the top of the lower antenna section and attaches directly to the cable. The system consists of two large cylindrical "choke" members facing one another, with the conductors of the coaxial feed cable tied to the opposing open ends of the "choke".

At the bottom end of the radiator proper, it is necessary to establish a condition which effectively duplicates that of an open conductor, such as occurs at the top end of the antenna. This is provided by an eight-rod ground plane, one half wavelength in radius. This is supplemented by a short choke placed on the antenna conductor slightly above the ground plane. In this manner, there is very low coupling between the bottom part of the antenna and the support structure, so that the antenna behaves like a pair of open end elements as indicated in the simple diagram for a center fed antenna structure.

The resultant cross sectional diagram of the antenna system is indicated in Figure 10. The main conductor carries discharge currents from the top of the antenna during conditions of corona and lightning due to atmospheric disturbances. This is the only conducting element which has the split construction. Contact during assembly is maintained by heavy connector pressure similar to that used in high power coaxial transmission line center conductors.

Structural support and weather protection of the antenna system is secured by mounting the metallic parts in a Fiberglas housing. The complete antenna has a weight of 54 pounds. It has the appearance indicated in the photograph Figure A.

The attenuation of current in this long array was measured with a probe in a

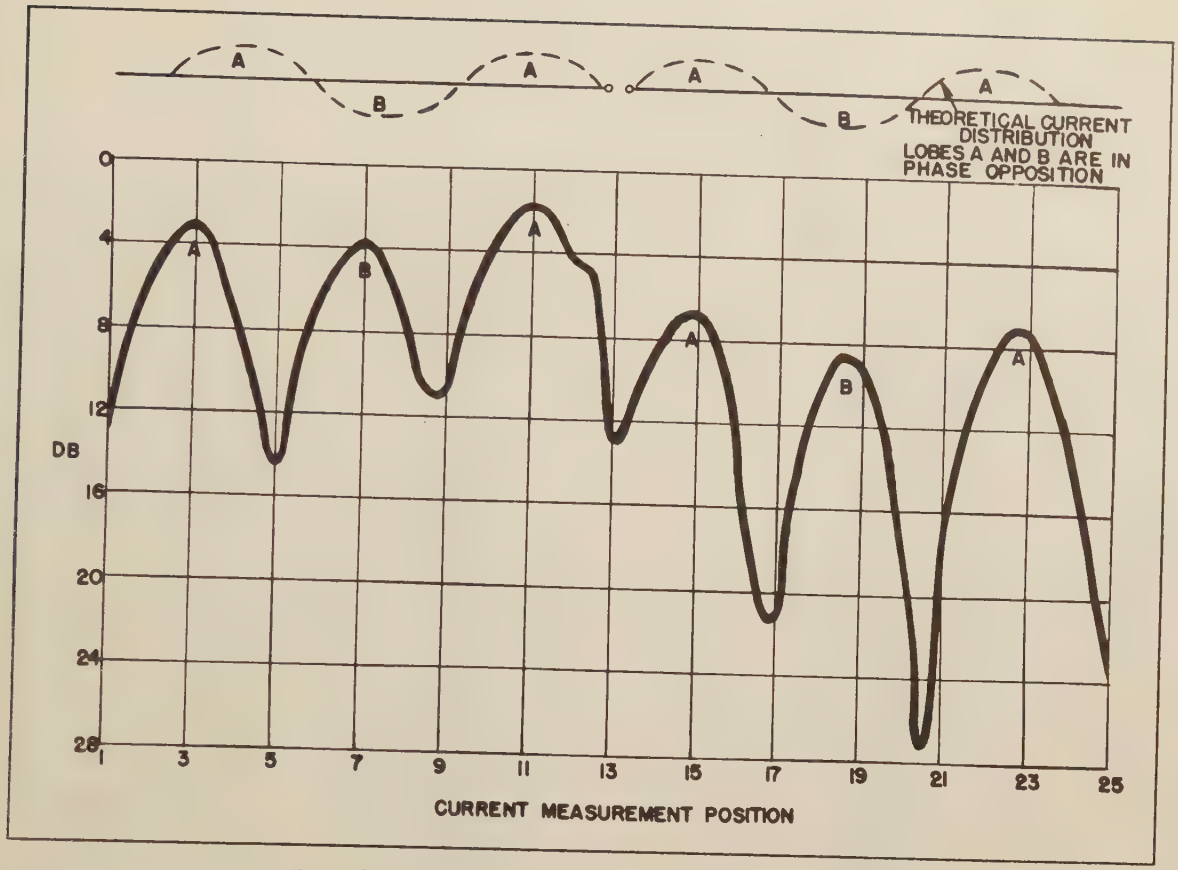

Fig. 8 - Current distribution, simple radiator.

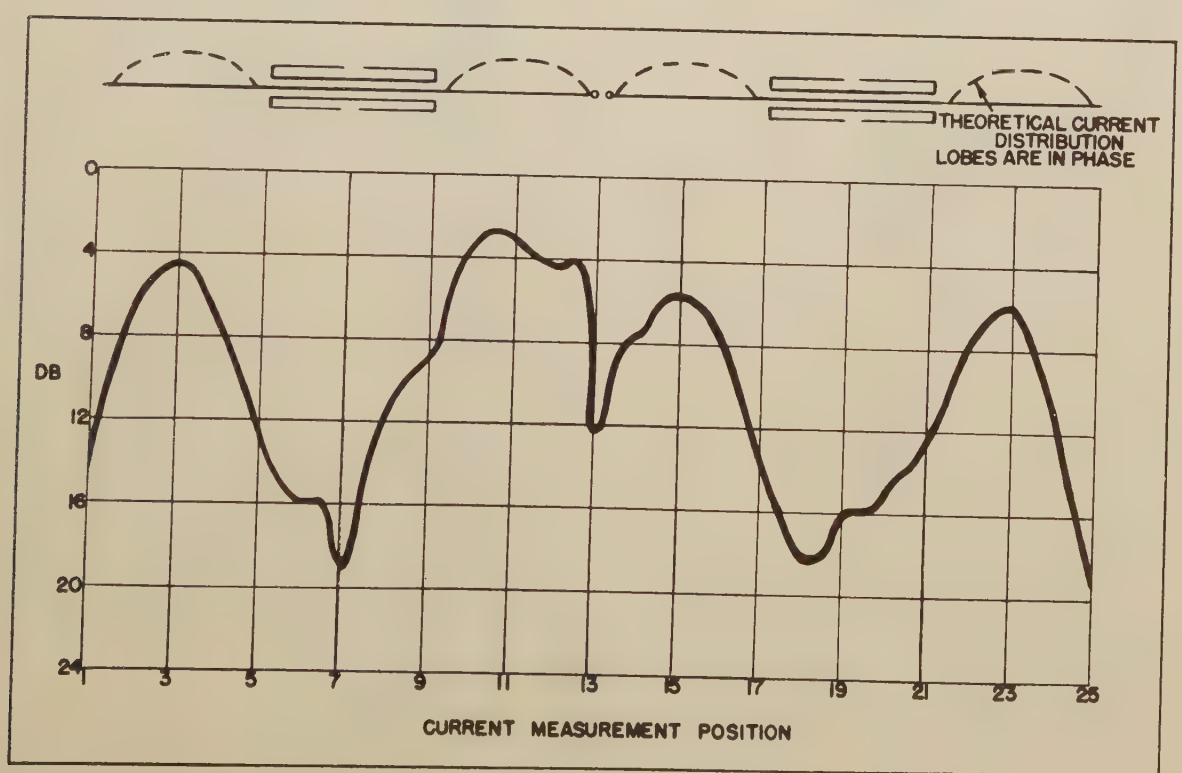

Fig. 9 - Current distribution, two-suppressor array.

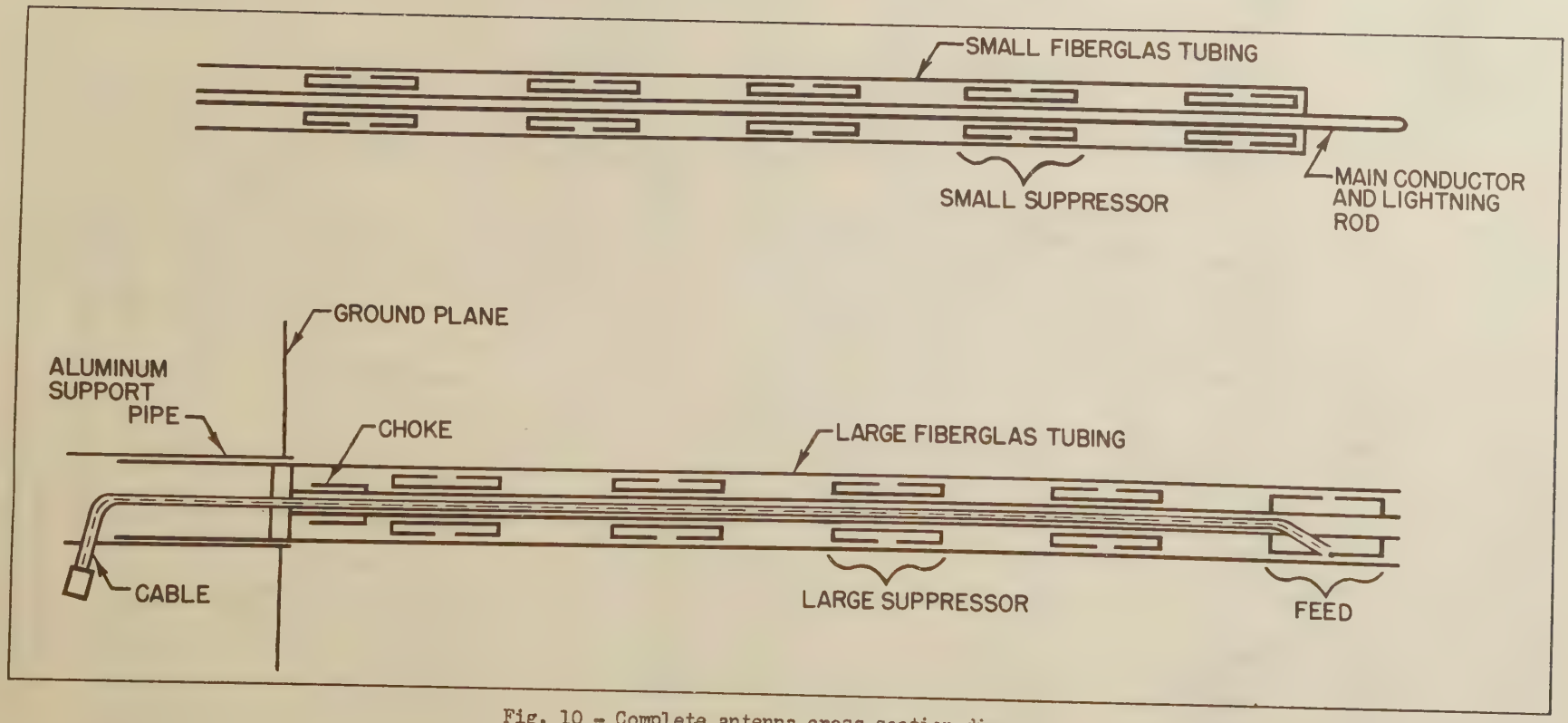

Fig. 10 - Complete antenna cross section diagram.

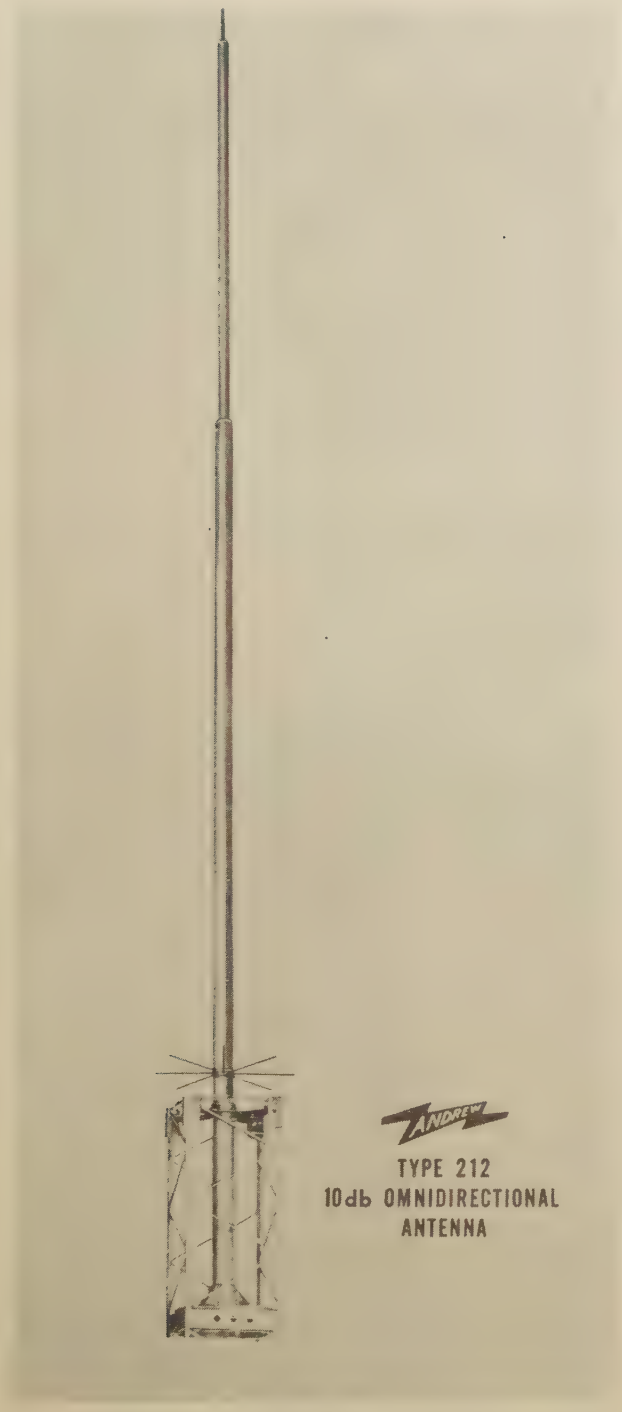

Fig. A

manner similar to that employed with the Franklin array. The results indicate a relatively linear drop in current from section to section of 3 db. This is .3 db per wavelength which is considerable improvement over the 10 db per wavelength measured for the Franklin array. It serves to show why a much longer effective array of this type can be used, compared with the Franklin array.

Performance

The antenna was designed to operate over the band 450 to 470 MC with one structure. The standing wave ratio characteristic is indicated by the impedance measured at the input to the matcher which is incorporated adjacent to the end seal at the remote end of the feed cable and is shown in Figure 11. The gain characteristic is shown in Figure 12.

The use of only one feed point and consequently only one feed cable makes it easy to handle the power rating problem. The standard antenna, Type 212, is equipped with an RG-8/U cable to permit a power rating of 200 watts. The Type 213 antenna for 250 watt applications, is equipped with an air dielectric cable with provisions for pressurization to prevent moisture from collecting on the insulators and cable fittings. This input has a 7/8" flange fitting.

Suppressor Details

The placement of the antenna within a Fiberglas protecting and supporting member involves some features which are shown in the photograph of the cross section, Figure B. The main conductor, which becomes a radiator between successive suppressor elements, is a relatively large tubing. The suppressor proper must be mounted concentrically over this conductor without metallic connection to allow the confined space to function as a transformer. A single insulating support at the center of its length provides proper alignment in a radial direction, and grooves rolled into the main conductor and the small cylinder of the suppressor provide for fixed axial positioning. The outer cylinders of the suppressors are spaced from the Fiberglas housings so as to reduce the dielectric disturbance at the open ends of the chokes produced by these outer cylinders. In spite of this choice, the chokes had to be shortened considerably as can be seen by the proportions of the tubular lengths. This spacing between the suppressor chokes and the housing also reduces the effect that collected snow or ice will produce in detuning these choke circuits. In order to maintain the entire suppressor in a coaxial relationship, three flexible plastic spacers were added at each of the ends. These spacers not only provide alignment but also prevent "rattling" of the suppressors within the

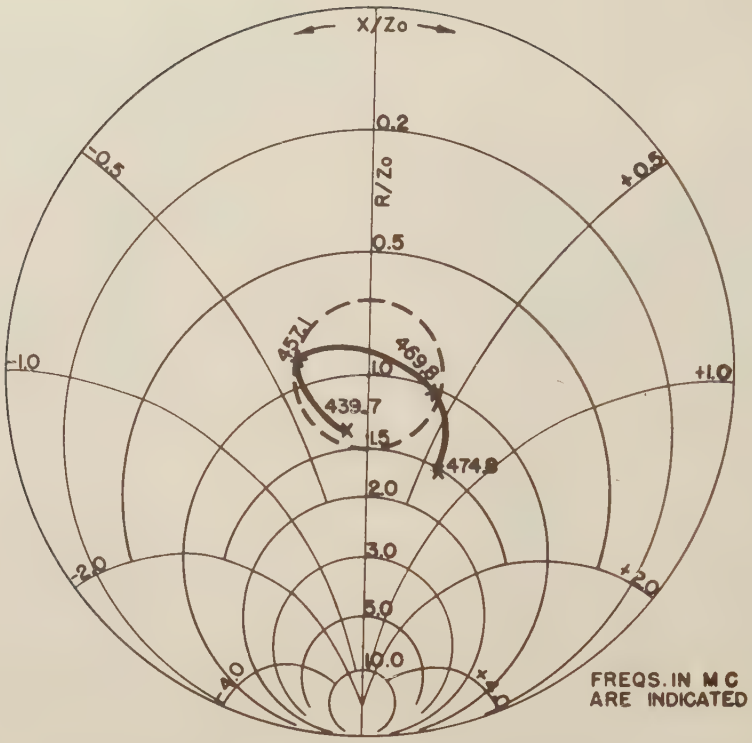

Fig. 11 - Impedance at matcher input.

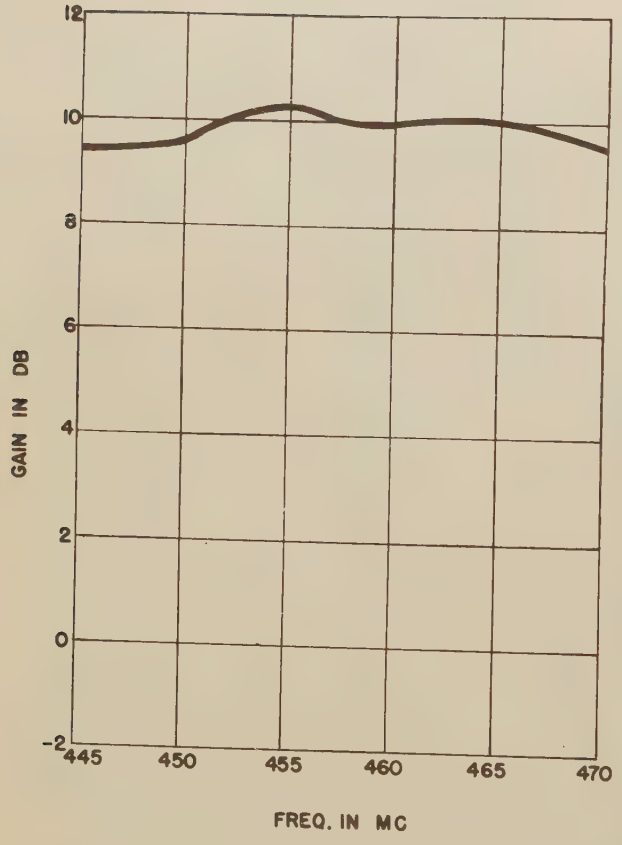

Fig. 12 - Antenna gain.

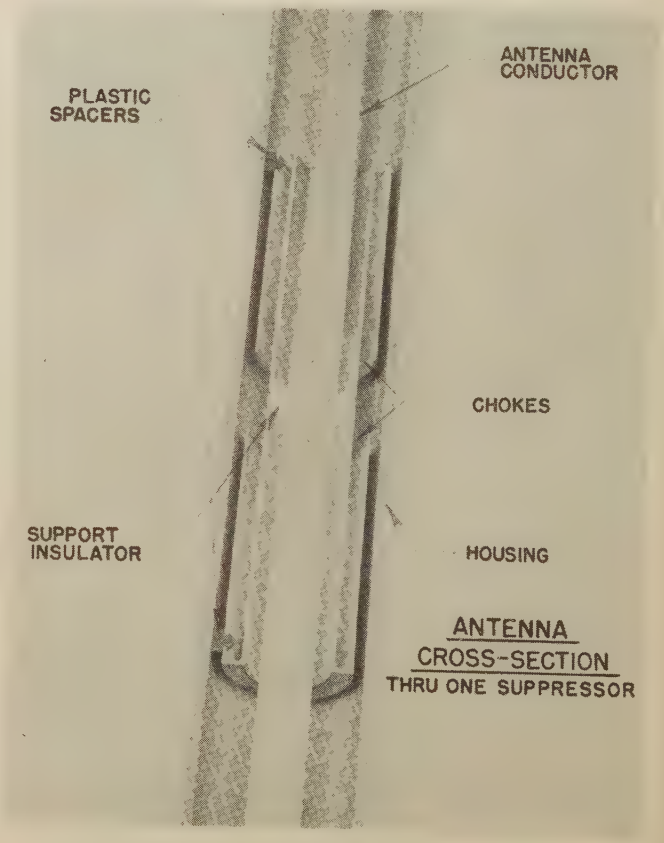

Fig. B

housing during vibration. Drain holes are provided to prevent accumulation of condensed moisture.

Conclusion

We have provided an unusually high gain antenna with outstanding features:

1. The feed system is reduced to the lowest possible degree of complexity.
2. Proper radiation conditions secured with rugged inexpensive elements.
3. One structure only, to cover the entire operating band.
4. Freedom from serious detuning by snow and ice.
5. Reliable lightning and corona protection.
6. Reduction of weight to a low value.
7. Sectionalized structure permitting ease of shipping and handling in confined spaces.

Acknowledgment

Valuable assistance by C. O'Kelly and P. Van Swol for extensive constructions and measurements is appreciated.

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THE END OF THE LINE

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Dallas, Texas

Summary

Discussion covers base station antennas in the 25-50 mc and 148-174 mc bands. Various types and combinations of antennas are discussed which produce shaped horizontal coverage patterns for non-circular areas so as to concentrate the radiation over the desired area. This approach to coverage is both economical from an investment standpoint and tends to reduce interference to other users.

Directional antennas with deep nulls on the back or side are effective in reducing co-channel, skip, desensitization, inter-modulation, and transmitter noise types of interference.

Better utilization of the sides of towers can be obtained by the use of side-mount antennas to obtain either circular or eccentric horizontal patterns. This permits greater antenna gain than otherwise possible and also allows a number of systems with sufficient frequency separation to occupy the same tower structure.

In radio communications, we think of the antenna as the termination--or end of the transmission line. Particularly is this true in the case of two-way radio systems where the station antenna represents both the incoming end for the receiver and the outgoing end for the transmitter. This dual role emphasizes the importance of the base station antenna in the over-all performance of a two-way radio system.

To accommodate the ever-increasing number of users in the mobile services, it has become necessary to split channels and go to narrower band widths. Manufacturers have pioneered in making split channels possible through the development and production of equipment which can now successfully operate in only one-fourth the band width which was required just ten years ago. Certainly, this marks achievement in utilization of the radio spectrum. Narrower channels and more stations, however, introduce technical problems of interference which can greatly compromise the gained channel utilization unless careful attention is given to location of stations and their antenna patterns.

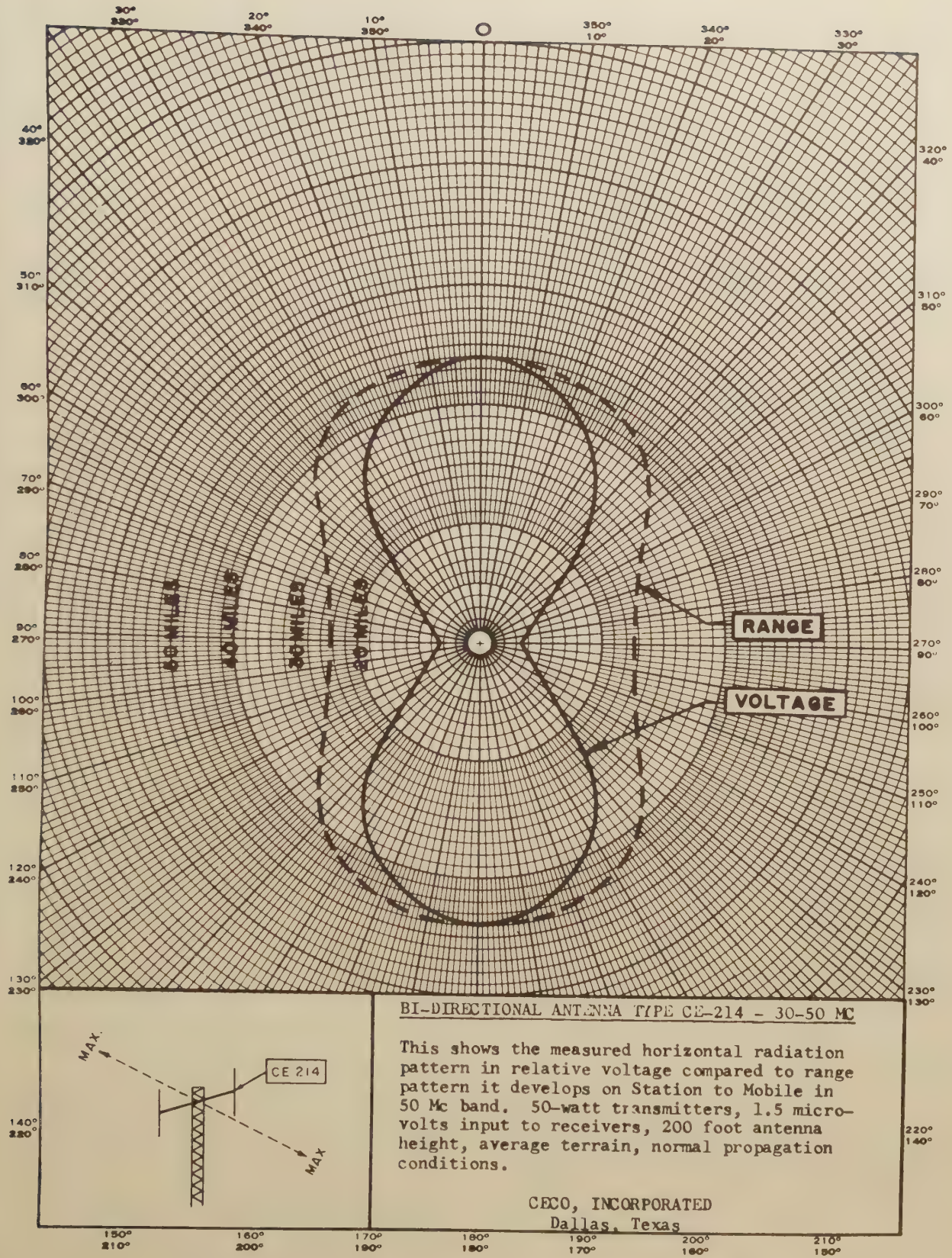
Radio communications, like other forms of communications, tend to jam up around operational centers. This means that many systems covering large areas may terminate in one small area. The resultant concentration of stations introduces not only co-channel interference, but interference between stations many channels removed--due to the effects of desensitization, inter-modulation and transmitter noise. It seems desirable at this state in the radio art that we look to patterning of antenna radiation to help reduce the problems of interference. If we are to control equipment power output, emission, and spurious radiation, then why not attempt some control of antenna radiation--at least put the signal where it is required and reduce it where it is not wanted. Let us examine some practical aspects of this approach.

General Mobile Coverage--Do We Need So Many Circles?

There seems to be a popular impression that the antenna horizontal pattern should be circular for general mobile coverage. True, there are many applications where circularity is the only solution, but what about the many other cases where circular coverage is not required. Immediately, there comes to mind the right-of-way operations, such as pipe lines, railroads, highway transportation, and highway maintenance. Certainly, these operations could employ some directivity along the right-of-way, and still maintain enough range to the sides to cover access roads and points of supply. Even though we think of mobiles in a random sense, still the mobile operations can be contained in a predictable area. If the required coverage area is drawn on a map with the operation center spotted, it will be seen that there are many cases where the operation center is offset from the center of the coverage area, or that the general shape of the coverage area departs considerably from a circular form.

When we look at antenna patterns. The tendency to show antenna patterns in terms of relative voltage has over-emphasized the directional character of the antenna in terms of what we really need to see--which is the range pattern. Figure 1 illustrates this point. Note how the lobe and null shape of the conventional Figure 8 bi-directional antenna smooths out to quite a nice rectangular form when shown in terms of range. The variation of 2/1 in range is far less than the 7/1 indicated by the voltage pattern. In order to more closely approximate the general shape of the range pattern, it is desirable to show antenna horizontal patterns in term of decibels (db) with respect to the common vertical half-wave dipole. Range charts such as shown in Figure 2 can then be used to plot the coverage for a given antenna height--or a tower height/antenna combination can be selected to best fit the area of coverage.

Figure 2 clearly shows how much easier it is to get range with antenna gain than by increasing tower height. At 160 mc the antenna gain of plus 5 db over a dipole equals the range increase obtained by going from a 200' to 400' tower with



BI-DIRECTIONAL ANTENNA TYPE CE-214 - 30-50 MC

This shows the measured horizontal radiation pattern in relative voltage compared to range pattern it develops on Station to Mobile in 50 Mc band. 50-watt transmitters, 1.5 microvolts input to receivers, 200 foot antenna height, average terrain, normal propagation conditions.

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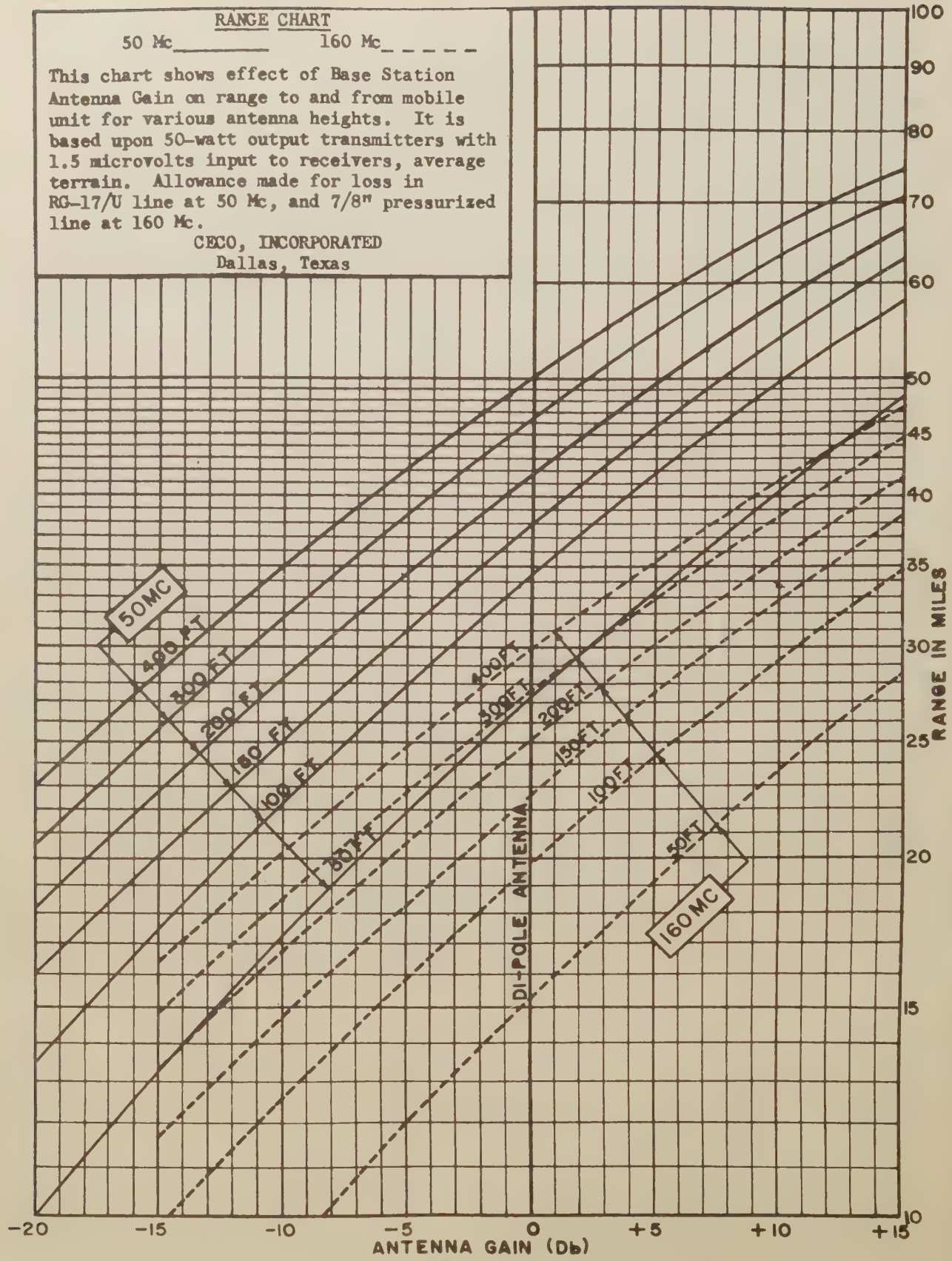
Fig. 1


RANGE CHART
50 Mc_____ 160 Mc_ _ _ _ _
This chart shows effect of Base Station Antenna Gain on range to and from mobile unit for various antenna heights. It is based upon 50-watt output transmitters with 1.5 microvolts input to receivers, average terrain. Allowance made for loss in RG-17/U line at 50 Mc, and 7/8" pressurized line at 160 Mc.
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50MC
400 FT
300 FT
200 FT
150 FT
100 FT
50 FT
400FT
300FT
200FT
150FT
100FT
50FT
160MC
DI-POLE ANTENNA
RANGE IN MILES
ANTENNA GAIN (Db)
100
90
80
70
60
50
45
40
35
30
25
20
15
10
-20
-15
-10
-5
0
+5
+10
+15

Fig. 2

dipole antenna of 0 db gain. The economic advantages to be gained are very real once the tower height reaches 100'. Good system engineering dictates the practice of getting the most db's with the least investment. It hardly need be pointed out that antenna gain can save considerable investment in towers and transmission lines.

Antenna Patterns for Non-Circular Areas

Rectangular shape with station off center.

Figure 3 shows the patterns of a six-element, uni-directional antenna in the 150-170 mc band employing two three-element Yagi's horizontally spaced one-half wave length and fed in phase. The inner black solid line is the horizontal pattern of this antenna showing decibels gain compared to a vertical half-wave dipole (0 db gain). The dotted lines show the range patterns which evolve for antenna heights of 100, 200, and 400 feet. The range is plotted out radially with 0 range at the center. These range patterns assume 50-watt transmitter output, with 1.5 microvolts input to the receivers, and the normal loss expected in 7/8" pressurized transmission line. The frequency of operation is in the 160 mc band. Even though this is considered a highly directive antenna, it will be noted that the range in the maximum direction is only somewhat more than twice that of the range in the poorest directions. This would be a desirable antenna for a system covering a rectangular area with the operation center shifted towards one end.

Key hole shape. Figure 4 shows the range patterns obtained in the 50 mc band using a six-element, uni-directional antenna (See Figure 3) in conjunction with an omni-directional antenna. The omni-directional antenna can be the conventional ground plane or coaxial type mounted on top of the tower or folded dipoles side mounted on the tower below the directional antenna. Both the directional and omni-directional antennas are fed in phase and connected to a single transmission line going to the equipment. The power is divided between the two antennas with a loss of approximately 3 db gain in the maximum of each. The antennas are, of course,matched to the transmission line. The 3 db lost by paralleling the two antennas could be saved by running separate transmission lines of equal length and using two receivers with the transmitter switched to the antenna desired. This shape coverage pattern is desirable where general all-around coverage must be maintained and yet there is an elongated portion of the area which cannot be reached with the omni-directional antenna. Another application would be that of general mobile coverage combined with increased range to another station in the system.

Rectangular shape station in center. Figure 5 shows a bi-directional antenna array consisting of two uni-directional antennas pointed 180 degrees apart and vertically separated in the mounting, a sufficient distance that the elements do not interfere. This particular set of range patterns covers the 160 mc band. The antennas are fed in phase and matched to the transmission line. This is the desirable type of coverage pattern for many right-of-way operations or for rectangular areas with the operation center in the center of the coverage area.

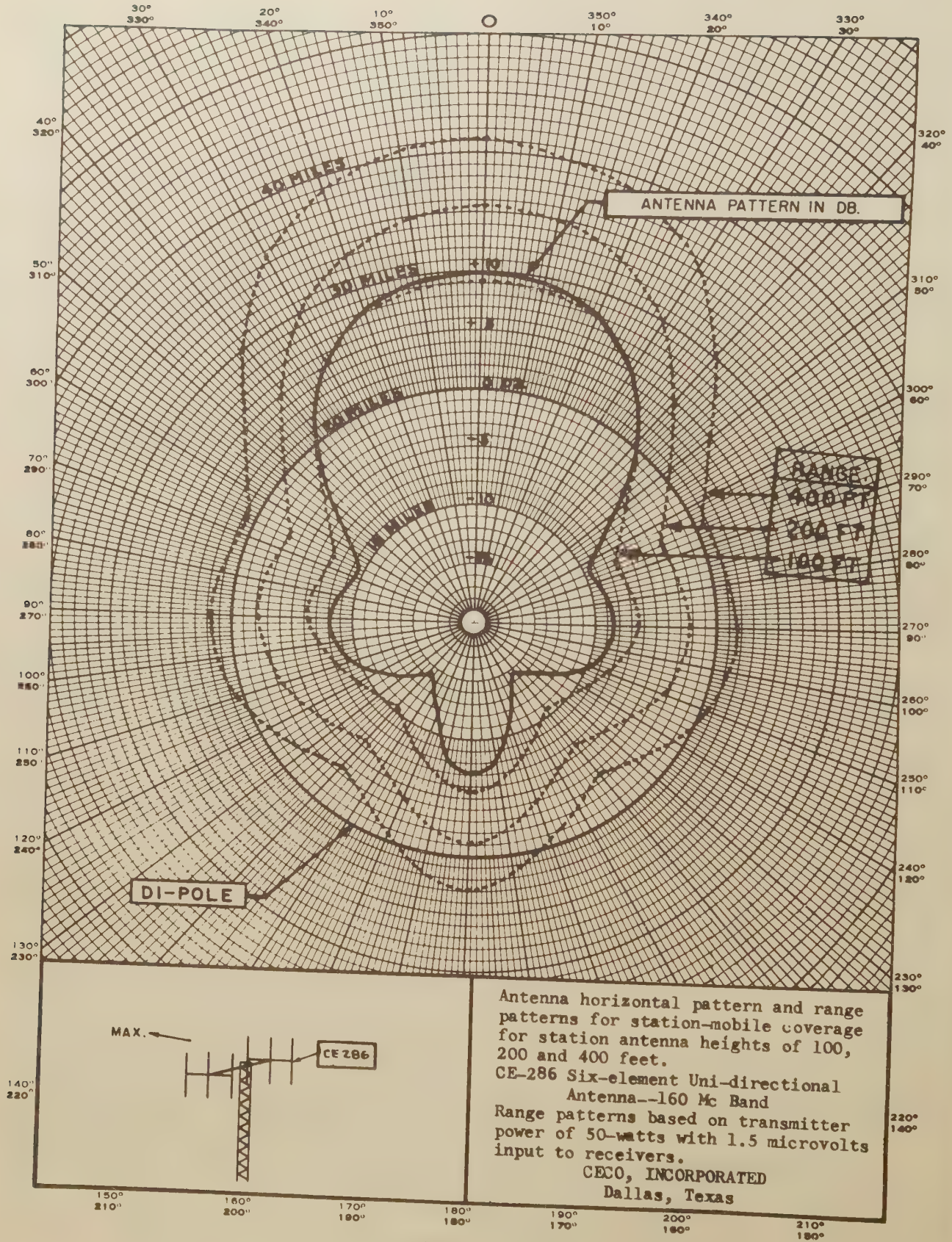
Sector Shapes. Figure 6 shows a more unique application of patterning wherein it is desirable to have maximum coverage over a sector less than 180 degrees with limited coverage in other directions. This is accomplished by using two separate arrays spread apart horizontally. Each array consists of four six-element, 10 db gain antennas vertically stacked one wave length center-to-center and fed in phase. The two resultant arrays are then paralleled so as to split power and matched to the transmission line. Such a pattern is applicable to sector coverage with the size of sector controlled by the spread angle between the two separate arrays.

Use of Antenna Directivity to Reduce Interference from Co-Channel Stations, Skip, Desensitization, Inter-Modulation and Transmitter Noise

Directive antennas designed with very deep nulls (high front-to-back or front-to-side ratios) often can be used very successfully to reduce or eliminate the above types of interference. Especially is this true in the case of interference caused by desensitization and transmitter noise where, because of necessity, stations close in frequency must be located in a confined area. Often as not, there is only one available mountain or hilltop location which must be shared by two or more stations. In many cases, the mountain is located to one side or one end of the area to be covered. By proper location of the antenna towers with respect to one another, it is feasible to work very much closer (both in frequency and physical spacing) than would otherwise be possible with omni-directional antennas. Figure 7 illustrates such an arrangement. Station No. 1 was first installed with an omni-directional (0 gain) antenna covering the area. It is a 250-watt (20 kc) narrow band station operating in the 48 mc range. Station No. 2, also a narrow band 250-watt station, desires to use the same mountaintop, but its frequency is only 40 kc removed from that of No. 1, and there is not room on top of the mountain to obtain the necessary 3 to 4 mile spacing from No. 1 required to prevent desensitization and transmitter noise interference. Consider that it is possible to locate station No. 2 in such a position that a directional antenna can be employed to cover the area and place its very deep null (minus 30 db) back towards No. 1. The 30 db attenuation in the null (1,000 times in power) then permits station No. 2 to be located only 1/4 mile away from No. 1 and the two stations can work without interference and cover their respective areas. If the frequency separation had been 80 kc, the physical spacing could have been reduced to only 400 feet.

There are similar applications in offshore petroleum operations and others which can use

(continued on page 28)


ANTENNA PATTERN IN DB.
40 MILES
30 MILES
20 MILES
10 MILES
+10
+5
-5
-10
RANGE
400 FT
200 FT
100 FT
DI-POLE
MAX.
CE 286
Antenna horizontal pattern and range patterns for station-mobile coverage for station antenna heights of 100, 200 and 400 feet.
CE-286 Six-element Uni-directional Antenna--160 Mc Band
Range patterns based on transmitter power of 50-watts with 1.5 microvolts input to receivers.
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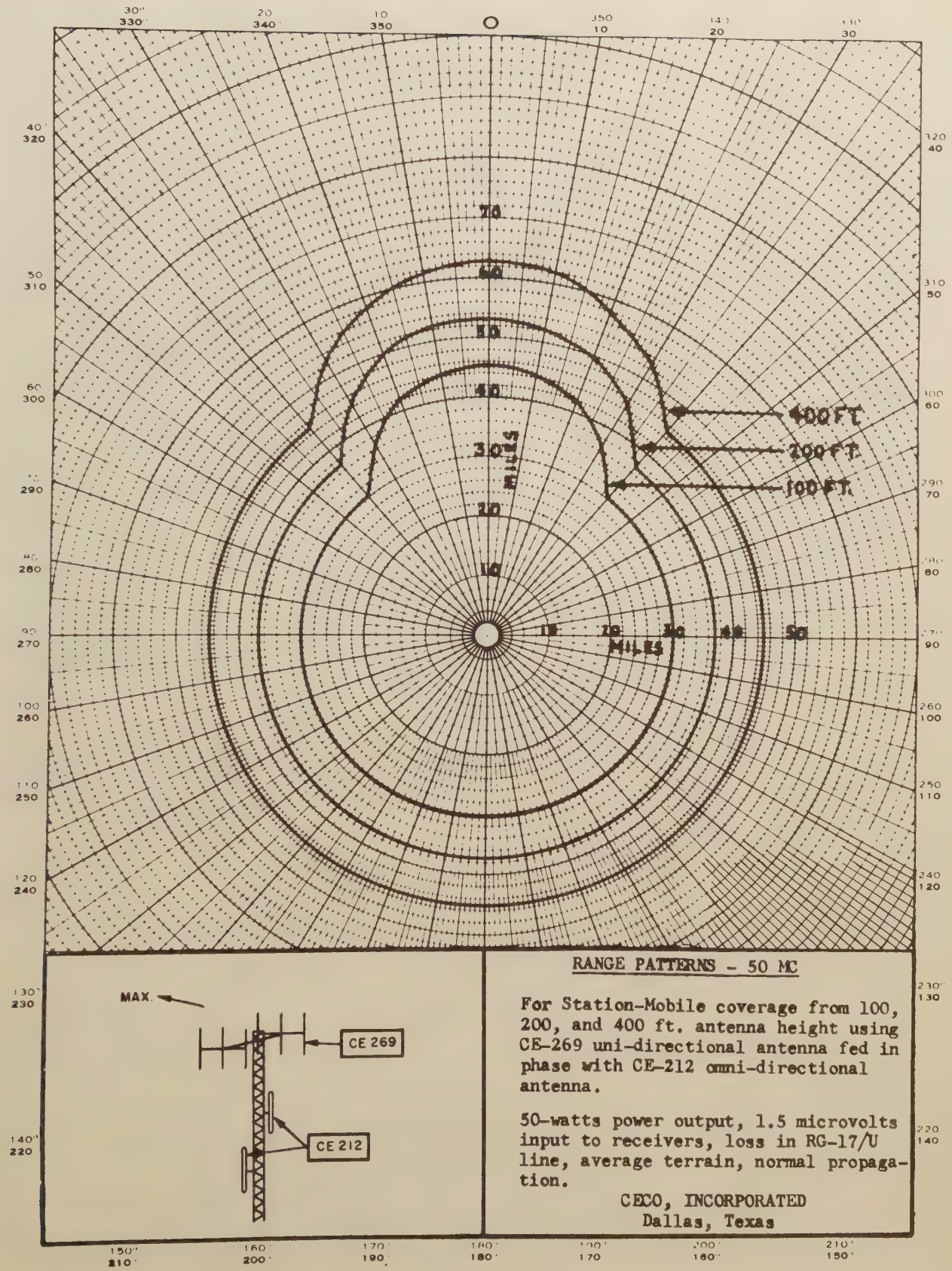
Dallas, Texas

Fig. 3



RANGE PATTERNS - 50 MC

For Station-Mobile coverage from 100, 200, and 400 ft. antenna height using CE-269 uni-directional antenna fed in phase with CE-212 omni-directional antenna.

50-watts power output, 1.5 microvolts input to receivers, loss in RG-17/U line, average terrain, normal propagation.

CECO, INCORPORATED
Dallas, Texas

Fig. 4

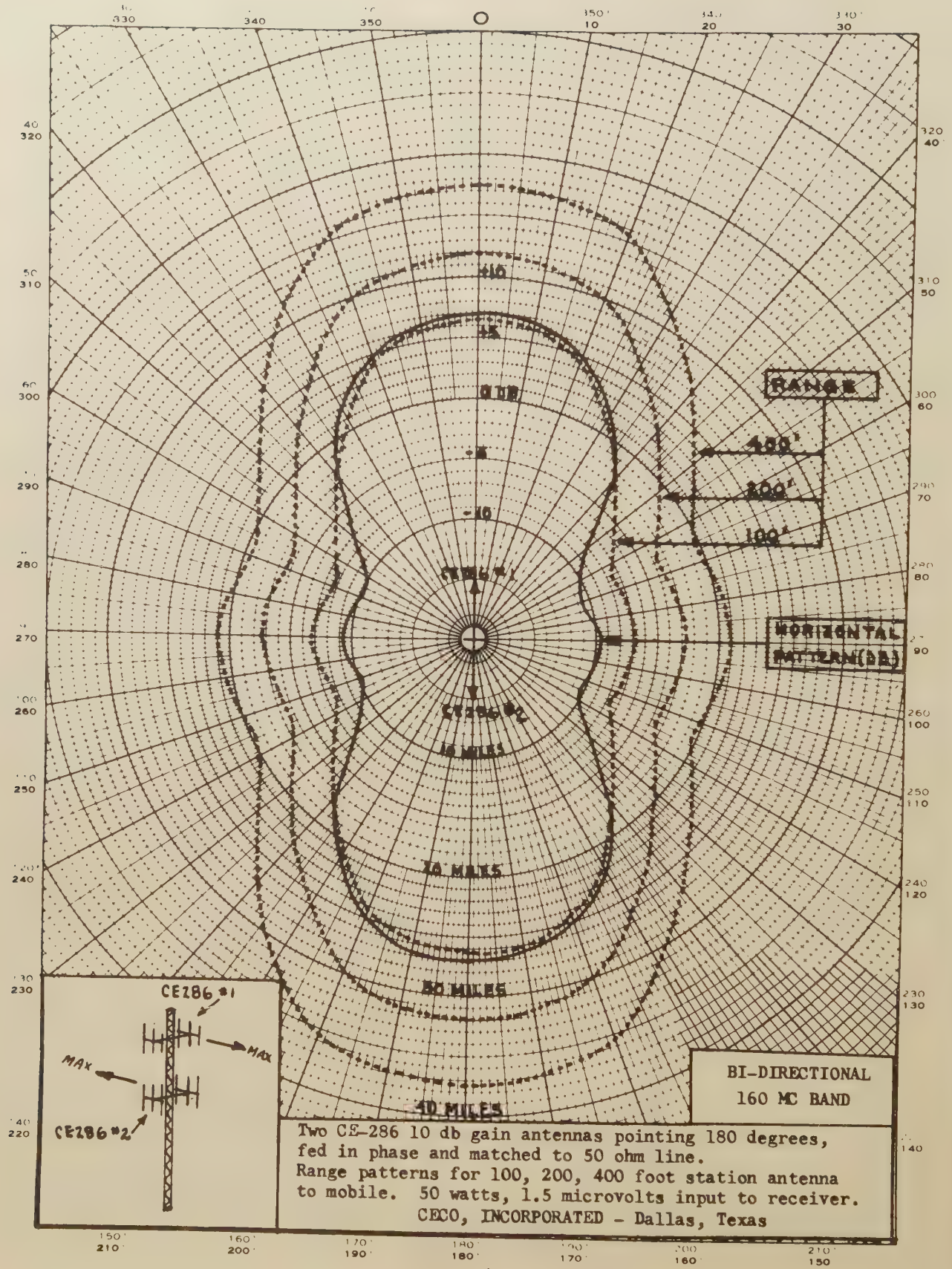

RANGE
400'
200'
100'
HORIZONTAL PATTERN(DB)
CE286 #1
CE286 #2
10 MILES
20 MILES
30 MILES
40 MILES
MAX
MAX
CE286 #1
CE286 #2
BI-DIRECTIONAL
160 MC BAND
Two CE-286 10 db gain antennas pointing 180 degrees,
fed in phase and matched to 50 ohm line.
Range patterns for 100, 200, 400 foot station antenna
to mobile. 50 watts, 1.5 microvolts input to receiver.
CECO, INCORPORATED - Dallas, Texas

Fig. 5

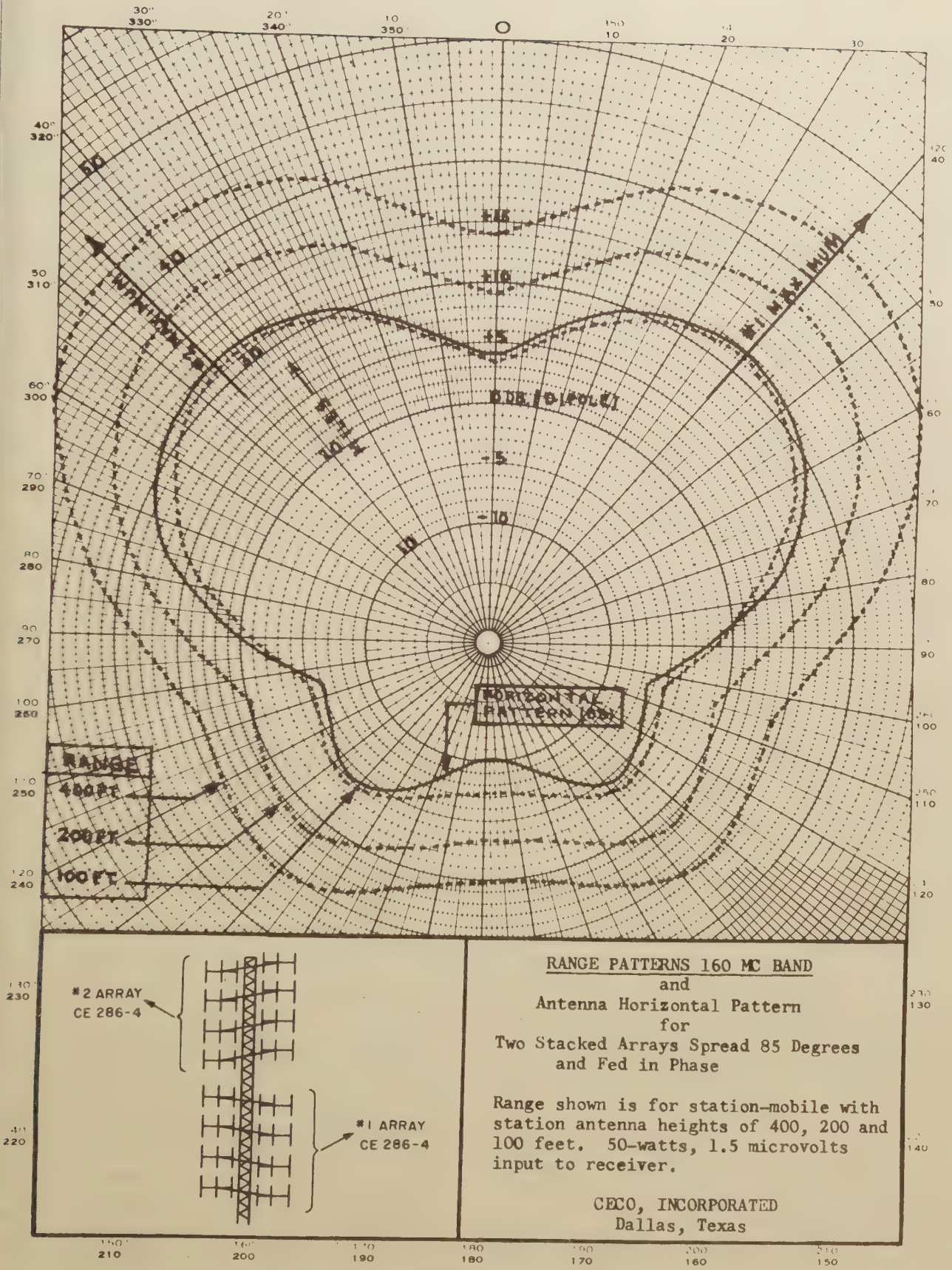
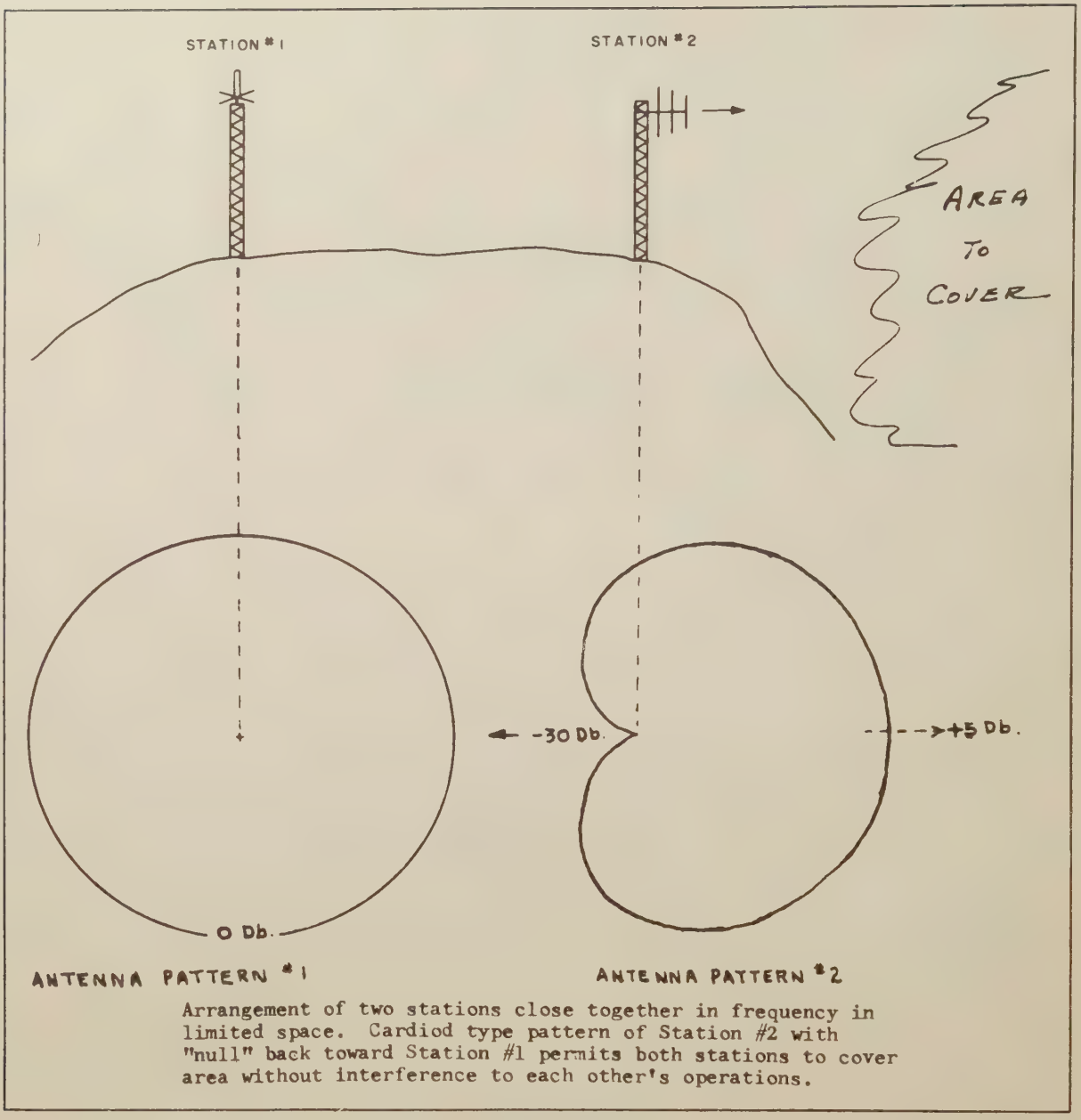

RANGE
400FT
200FT
100FT
HORIZONTAL PATTERN 160M
#2 ARRAY CE 286-4
#1 ARRAY CE 286-4
RANGE PATTERNS 160 MC BAND
and
Antenna Horizontal Pattern
for
Two Stacked Arrays Spread 85 Degrees
and Fed in Phase
Range shown is for station-mobile with station antenna heights of 400, 200 and 100 feet. 50-watts, 1.5 microvolts input to receiver.
CECO, INCORPORATED
Dallas, Texas

Fig. 6



Arrangement of two stations close together in frequency in limited space. Cardiod type pattern of Station #2 with "null" back toward Station #1 permits both stations to cover area without interference to each other's operations.

Fig. 7

(continued from page 23)

this same approach to effectively reduce the required physical spacing for a given frequency separation. Cooperation between users and a little engineering planning can provide many workable solutions to problems encountered where stations must be concentrated in limited areas.

The same technique often can be successfully used to reduce or eliminate skip interference such as the harmonic radiation of very powerful HF broadcast stations of co-channel skip from other two-way systems. 20 or 30 db of attenuation will in most cases reduce the interfering signal to a level where the mobile units (not in the null sector) can "capture" the station receiver.

Better Tower Utilization—Side Mounting of Antennas

The only purpose a tall tower serves at VHF and higher frequencies is to elevate and support the antenna. Since a high tower represents a considerable investment, it is only logical to use as much of the tower as practicable in order to give additional antenna gain—or to support additional antenna systems. Many tall broadcast, TV, FM and community TV towers use just the top or upper portion of the tower. Rental space on the sides often is available at reasonable rates. In addition, many two-way users are finding that their high towers are a good investment due to rental return from other users whose frequencies

permit occupancy without interference. These tower-sharing arrangements are desirable, both from the economic standpoint and the lessened hazard to air navigation due to fewer towers.

Side mounting of antennas. Most directive antennas (horizontal plane) retain their essential directional characteristics when mounted on the side of a tower because the radiation is directed out away from the tower. Conventional type half-wave coaxial or ground plane antennas, however, show considerable distortion from a circular pattern when mounted on the side of a tower. The resultant directivity and distortion from a circular pattern is difficult to predict because it depends on the size tower, frequency, and spacing from the tower. Figure 8 shows patterns measured using a vertical folded ground plane mounted on a leg of a triangular tower with legs 18 inches apart for a frequency in the 49 mc range. The spacing of 8 feet out (0.4 wave length) produced the least distortion, but the mounting becomes more difficult and there is an appreciable moment load placed on the tower. Greater pattern distortion can be expected for larger size towers.

An omni-directional antenna designed for side mount. Figure 9 illustrates a side mount antenna in the 25-50 mc range which has been successfully used over the past 7 years to provide essentially a circular horizontal pattern with gain over a coaxial or ground plane antenna. This antenna consists of two sections which are mounted on opposite or adjacent legs of a tower and staggered in the vertical plane so that there is a spacing (not critical) of between 1/2 and 1 wave length between centers measured vertically. Each section consists of a folded half-wave dipole held at a fixed distance from the tower leg by a mounting which is an integral part of the antenna. The mounting holds the antenna from 15 to 8 inches out from the tower leg depending on frequency in the 25-50 mc range. Both dipoles are fed in phase and matched to the transmission line. The reactance which the tower introduces at this close spacing is taken into consideration in the design and adjustment of the antenna.

The horizontal spacing between dipoles is the limiting factor in obtaining a circular pattern. In directions where both dipoles are equidistant from the source, the voltages add in phase. The resulting distortion from a circular shape does not become serious until the horizontal spacing between dipoles approaches a quarter wave length. Therefore, to retain fairly good circularity, opposite or alternate leg mounting should not be used on towers where the horizontal spacing between dipoles exceeds a quarter wave length of the operating frequency. The maximum tower size (leg to leg distance) for various frequencies is as follows:

25 mc	6 ft.
30 mc	5 ft.
35 mc	4.25 ft.
40 mc	3.75 ft.
45 mc	3.3 ft.
50 mc	3 ft.

Colinear arrangement of side mount antennas. (Eccentric Pattern) Where the tower is of very large size, a usable pattern is obtained by mounting the folded dipoles vertically in line (colinear) on the same leg. (See Figure 10) A spacing of 3/4 to one wave length (not critical) center-to-center between dipoles gives optimum gain. The horizontal pattern obtained will show gain over the alternate/opposite leg mounting towards the direction the dipoles face, with loss in gain on the back side. The pattern becomes eccentric—shifting towards the direction the dipoles face. On towers measuring from 1/2 to 2 feet on a side, the difference in gain between the forward and back directions is about 6 db. On very large towers (5 to 10 feet on a side) this difference may be as much as 10 db. Since there is gain in the forward direction, however, radiation to the back will not be too much less than that of a dipole.

It will be noted the tables in Figures 9 and 10 show the minimum tower height to consider. This is based on loss of antenna height as the antenna array spreads down the tower. The center of the array is considered the effective height of the antenna. Allowance is also made for the increased loss in feed lines as the array becomes longer.

Side mount antenna reduces precipitation and dust particle static. Experience has shown the side mount antenna much less susceptible to static charge caused by charged clouds, dust and snow. Being on the side below the top of the tower, static voltages do not build up as they do on a top mounted antenna. The grounded design further helps discharge any static voltage build up tendency. Wrapping of the elements with "Scotch" or similar type high voltage tape further reduces precipitation static buildup. On some installations, side mount antennas have worked thru high precipitation static periods that completely blanked out a system with coaxial or ground plane antenna on top of the same tower.

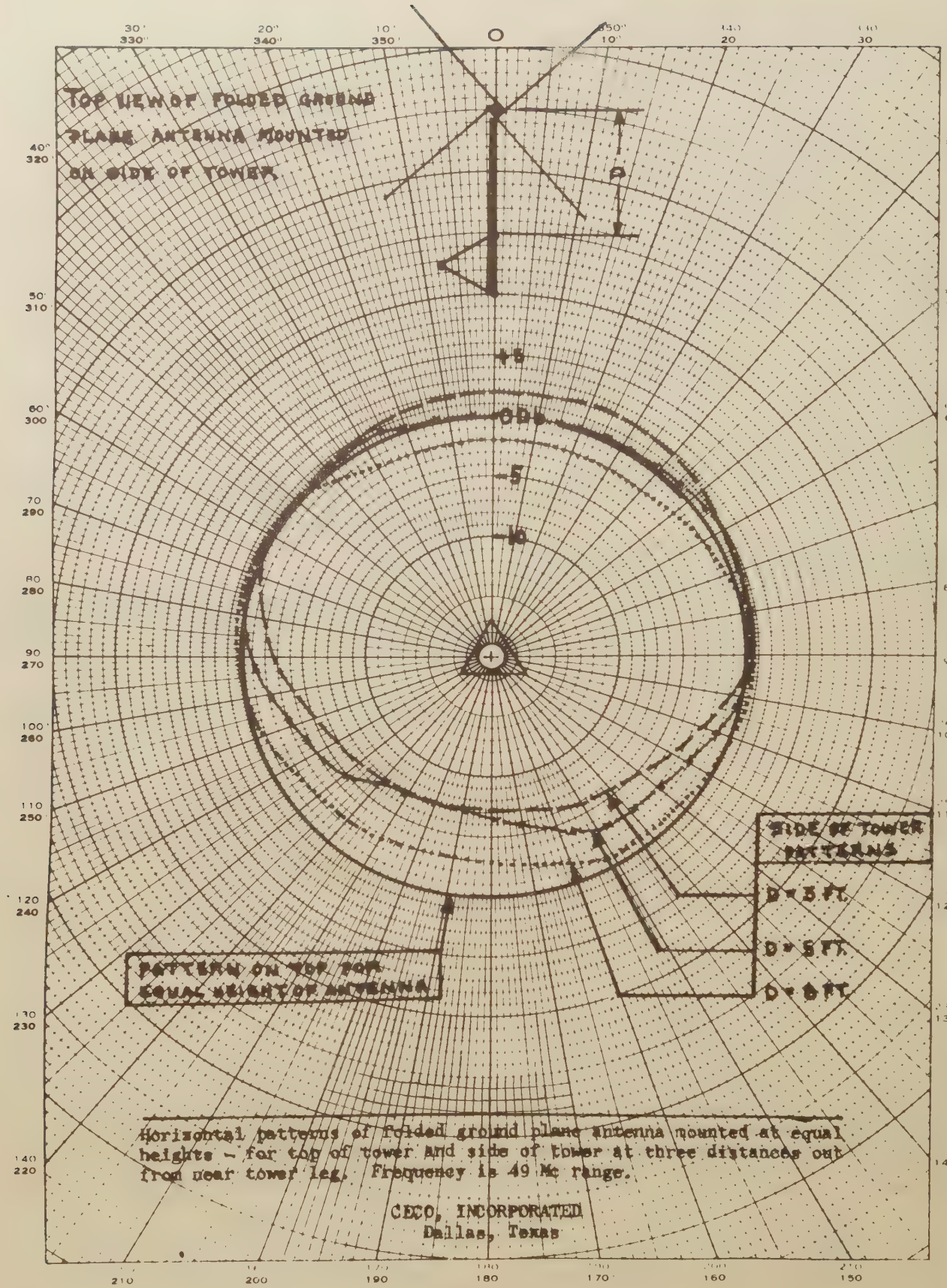
The side mount antenna also is easy to install and get to for inspection or test. Since it projects a minimum distance from the tower--it is favored from the mechanical standpoint in that it presents minimum tower load and also favorable appearance.

Side mount antennas of sufficient frequency difference can be mounted at parallel levels on different legs so as to permit maximum tower utilization by different systems.

Summary

Antennas hold considerable promise of improving over-all performance in mobile two-way radio systems:

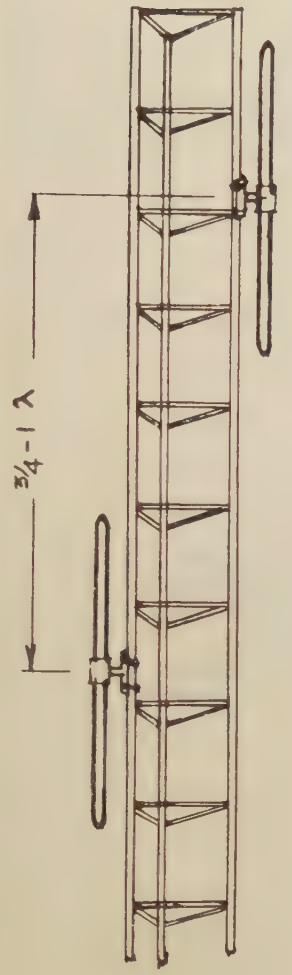
1. Directive and pattern antennas can be profitably employed to concentrate the radiation where it is required and reduce it where not wanted. This means lower over-all system investment and less interference to other systems.



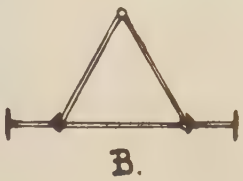
Horizontal patterns of folded ground plane antenna mounted at equal heights – for top of tower and side of tower at three distances out from near tower leg. Frequency is 49 Mc range.

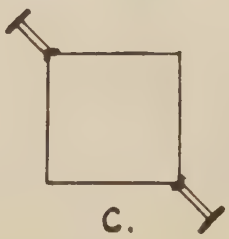
CECO, INCORPORATED
Dallas, Texas

Fig. 8



CE-212 side-mount antenna mounted on alternate legs of triangular tower (A&B) and on opposite legs of square tower (C) for essentially a circular horizontal pattern. Mounting (B) gives greater circularity than does (A).

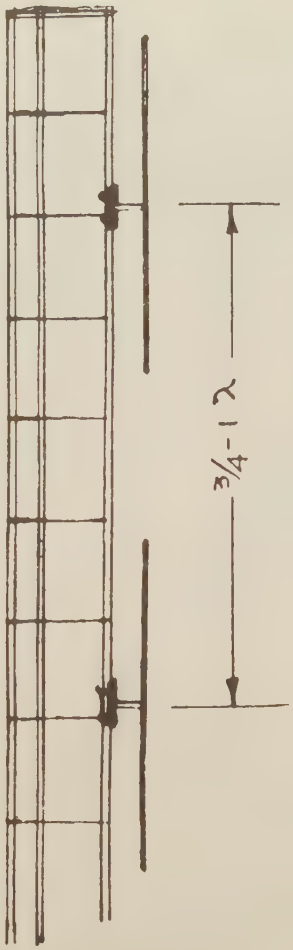




The following table gives gains compared to a vertical half-wave dipole at the same effective height for typical installations — for a circular pattern using the opposite/alternate leg mounting.

Antenna Type	No. of Dipoles	Circular Pattern Opposite/Alternate Leg Gain in DB Max.	Min.	Total Spread on Tower (40 mc)	Minimum Tower Height to Consider
CE-212	2	≠ 2.5	≠ 0.5	30 ft.	100 ft.
CE-212-4	4	≠ 5	≠ 3.0	66 ft.	250 ft.
CE-212-8	8	≠ 7.0	≠ 5.0	138 ft.	450 ft.

Fig. 9



CE-212 side-mount antenna mounted on same leg (colinear) on tower to give eccentric horizontal pattern favoring sector antennas face.

The following table gives gains compared to a vertical half-wave dipole at the same effective height for typical installations -- for an eccentric pattern with dipoles mounted on the same leg (colinear).

Antenna Type	No. of Dipoles	Eccentric Pattern Same Leg (Colinerar) Gain in DB Max. (0 Degrees)	Min. (180 Deg.)	Total Spread on Tower (40 mc)	Minimum Tower Height to Consider
CE-212	2	≠ 5.0	-- 3.0	30 ft.	100 ft.
CE-212-4	4	≠ 7.5	-- 0.5	66 ft.	250 ft.
CE-212-8	8	≠ 9.5	≠ 1.5	138 ft.	450 ft.

Fig. 10

2. Performance gained thru use of antennas also is economical from a maintenance standpoint, since properly designed antennas do not require maintenance as do towers, and radio equipment.

3. Many problems of interference due to co-channel and harmonic skip interference, desensitization, inter-modulation and transmitter noise can be solved by directive antennas designed with deep nulls on the back or side of the pattern.

4. Thru the use of side mount antennas, better utilization can be made of towers to obtain additional gain and improve system performance. Side mount antennas also permit the use of towers by a number of different systems. This sensible approach offers economic advantages and helps safety of air navigation thru reducing the number of towers required.

The antenna may be at the end of the transmission line, but the end of the line has not been reached yet in terms of realizing potential application of antennas in two-way radio communications.

SOURCES OF INTERFERENCE INHERENT IN VEHICULAR ELECTRICAL SYSTEMS

Brooks H. Short
General Motors Corp.

EDITOR'S NOTE

Mr. Short advises that 99% of the information included in his talk has previously been published. For this information, he references QST, April, 1952 - GENERAL MOTORS ENGINEERING JOURNAL, March and April, 1954. (Volume I, Issue No.5)

A NEW ARM FOR VEHICULAR COMMUNICATIONS

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Summary -- A comparative system study has been made to determine the performance requirements of a pocket carried receiver, which is compatible to existing land-mobile vehicular communication systems and can be used to extend their range of operational flexibility. The study employs a medium frequency analysis as a model. Using this method, a similar process yields the minimum performance specifications for frequencies of 43 and 150 mc. It is determined that such a device can be practically utilized within the desired range of coverage. A typical receiver now in production is described and a discussion of present and future applications illustrated.

Vehicular communications needs a new arm to extend its useful range of service. The growing spectrum congestion has become a limiting obstacle which does not seem to have a quick and ready solution. Even the adoption of F.C.C. Docket 11253 will not provide the answers that we require at this time. A means for extending the vehicular communications service into what appears to be normally inaccessible areas would help to alleviate the traffic problem and extend the useful range. An analytical method will be presented to determine what frequency is best for extending the range of a vehicular unit by means of a personally carried pocket type miniature receiver. An examination of the potential performance possible at lower frequencies will help us to gain an appreciation of the most economical and practical approach to the problem. To this end, we will consider pocket carried receivers operating in the 3 mc band before considering the requirements for the higher frequencies of 30-50 mc and 152-174 mc.

The operational limitations of a land mobile system's effectiveness is determined by the physical problems of the operator being confined to the vehicle for communication with his base station and the electrical limitation of the spectrum traffic loading. A solution to the monitoring problem is possible through the use of selective calling equipment which will leave a call registered. This has two disadvantages; first, it is not an adequate answer to the urgency of a communication; and, second, it increases the overall traffic load by necessitating a repeat of the message. Often a communication band is used for a considerable amount of traffic between closely spaced units and it is desirable to find a means to relieve this traffic. Again, it is desirable to extend the effective coverage of the mobile unit when it is operating in a fringe area.

A practical solution to these problems is the extension of the communication facility to the person on foot, whereby he can maintain contact with the mobile unit through a pocket carried receiver and transmitter unit. Of necessity, such equipment as this is required to be light in weight, small in size and easily carried on the person. This demands a form factor similar to a pack of cigarettes or any other small package that will conveniently fit in a shirt pocket or upper coat pocket. The equipment must be compatible in frequency and method of modulation and must have comparable sensitivity to the existing mobile equipment with which it will operate. Reasonable battery life is required in order to permit continuous monitoring of the circuit. It must have a means for rejecting extraneous signals and noise. Such a unit would find its maximum utilization through the medium of an automatic repeating facility which could be provided by means of a carrier operated relay, operating the vehicle transceiver set. With the advent of mobile equipment using transistors for both circuit work and power supplies, the battery drain for standby purposes would be within reason.

This discussion will be confined to the receiver only and will, after an analysis of medium frequency performance, show a method of determining system gain requirements at 30 and 150 mc. The performance of a typical receiver at 150 mc will be discussed, as well as the circuit features which are required for its functions. Such a unit has present and future applications which fit into every type of vehicular operation, and also extend these operations beyond that which we have been accustomed to expecting. A man on foot can always go many places where an automobile with four wheels cannot.

To establish a method of system analysis, we will examine the signal-to-noise performance and system gain characteristics of a medium frequency receiver and system. There are calculation tools which will permit us to estimate the probable performance of such a receiver using a ferrite rod antenna. Figure 1 is an equivalent circuit of the ferrite loop antenna[1] which essentially is a step-down transformer with a tuned primary. A typical 3 mc antenna would consist of a lithium ferrite rod, eight inches long, and 33/100 of an inch in diameter. Seventy-five turns of No. 26 wire, space wound, will resonate in the region of 3 mc, with a 50 mmf. capacitor. The most significant properties of the ferrite rod antenna is its Q and permeability characteristics[2]. When the antenna is loaded to the receiver input, the Q will be considerably less.

Figure 2 itemizes some typical ferrite materials with their characteristics of Q and permeability given for three frequencies. The

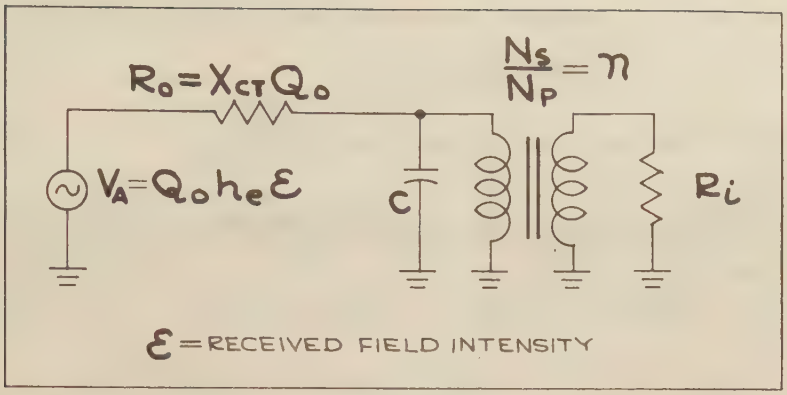


Fig. 1 - Equivalent circuit of ferrite loop antenna.

FREQ	MATERIAL	μ_o	Q_o
1.0 MC	Ni Fe	125	350
3.5 MC	Li Fe	100	150
10.0 MC	Li Fe	100	50

Fig. 2 - Properties of typical ferrite materials.

most common materials are nickel ferrite at the lower frequencies in the broadcast band and lithium ferrite used at frequencies 3 mc or greater. The permeability for a given material will remain fairly constant over a wide frequency range. The Q, however, deteriorates rapidly due to the circulating losses of the material. The two characteristics which will most directly control the gain or loss of the antenna will be the tuned impedance and the effective height.[1 & 2] To calculate the gain or loss, we need to know the turns ratio and equivalent voltage of the antenna.

Figure 3 itemizes seven steps by which the antenna gain may be derived. The turns ratio[1] is limited by the image rejection conversion factor which appears under the radical in the denominator as the numerical value $1\frac{1}{2}$ in equation 2. With this knowledge in hand, it is possible, then, to calculate the effective height of the antenna. The equivalent voltage of the antenna can now be determined and established on a dipole-to-dipole reference basis. With this information, we may determine the power which is available from the loop for the receiver input. If we compare this power with the power available from a dipole matched to the receiver input, we will then have the antenna gain or loss. A typical 3 mc antenna will show a loss of 17 db referenced to a dipole.

In Figure 4 we have outlined a method of derivation of carrier-to-noise ratio of the medium frequency receiver[1]. To do this, we must first establish typical performance characteristics. The most important ones are the audio output signal-to-noise ratio, the R.F. and audio bandwidth and the R.F. input stage noise figure. It is also desirable to establish the transmitter modulation index since the required field intensity for the desired signal-to-noise ratio will be dependent upon the sideband power, as well as upon the carrier power. After we have derived the required signal power input, we can then determine the thermal noise in the R.F. bandpass and increase this by the transistor noise value to obtain the total antenna and input noise power. The carrier-to-noise ratio thus derived is the performance needed to just achieve the desired signal-to-noise ratio in the audio output.

We are now ready to determine the system gain needed and the first step will be to evaluate the receiver sensitivity relative to the atmospheric noise, man-made interference and galactic noise[3]. Figure 5 is a graph of seasonal noise values found between 35° N. latitude and 45° N. latitude. North of this limit, the noise values would be generally lower and south of these limits, the noise values would be generally higher.

You will observe that the peak amplitude period occurs in the three to four hours preceding and following midnight. The maximum difference between winter and summer rarely exceeds more than 8 to 10 db. The galactic noise and man-made interference is constant over the four seasons, as well as over the 24-hour period. The value of galactic and man-made noise shown here has been averaged for the 24-hour period and the four seasons, since there is a very small variation over the 24-hour period. The carrier-to-noise ratio of a typical 3 mc receiver is approximately 40 db. If the receiver is designed with a sensitivity limited to achieve this performance, it will then only be susceptible to the atmospheric, man-made or galactic noise during the peak amplitude period. If additional sensitivity is desired, it will be limited by the amplitudes of

R_o (TUNED IMPEDANCE) $= X_{CT} Q_o$ (1)

η (TRANSFORMER TURNS RATIO) $= \sqrt{\frac{Ri}{1.5 R_o}}$ (2)

h_e (EFFECTIVE HEIGHT OF ANTENNA) $= \frac{2\pi NA \mu_o}{\lambda}$ METERS (3)

N = NUMBER OF PRIMARY TURNS

A = AREA OF ONE TURN IN SQUARE METERS

V_A (EQUIVALENT VOLTAGE OF ANTENNA $= h_e E Q_o$ VOLTS (4)

$E = \sqrt{49.2} \times 10^{-3}$

FIELD INTENSITY AT 1 KM RADIATED
FROM A DIPOLE WITH 1 WATT INPUT

P_L (POWER AVAILABLE FROM LOOP) $= \frac{(\eta V_A \frac{Q}{Q_o})^2}{Ri}$ WATTS (5)

P_D (POWER AVAILABLE FROM DIPOLE) $= 2.7 \left(\frac{\lambda}{4\pi R}\right)^2$ WATTS (6)

R = DISTANCE IN METERS

ANNTENNA GAIN (DB) $= 10 \log \frac{P_D}{P_L}$ (7)

Fig. 3 - Operating characteristics of ferrite loop antenna.

$\mathcal{E}$ (FIELD INTENSITY FOR DESIRED S/N) $= \frac{S/N \sqrt{4KtBfaRoF}}{h_e Q_o Mi}$ VOLTS/METER

$4KtBfa$ = THERMAL NOISE POWER IN AUDIO BAND (1)

F = TRANSISTOR NOISE FIGURE

Mi = TRANSMITTER MODULATION INDEX

$V_A = h_e \mathcal{E} Q_o$ (2)

V_s (SIGNAL VOLTAGE INPUT TO TRANSISTOR) $= \eta V_A \frac{Q}{Q_o}$ VOLTS (3)

P_s (SIGNAL POWER INPUT) $= \frac{V_s^2}{Ri}$ WATTS (4)

P_{THN} (THERMAL NOISE POWER IN RF BAND) $= 4KtBf$ WATTS (5)

P_N (RECEIVER INPUT NOISE POWER) $= P_{THN} XF$ WATTS (6)

$C/N = 10 \text{ LOG } \frac{P_s}{P_N}$ DB (7)

Fig. 4 - Derivation of c/n.

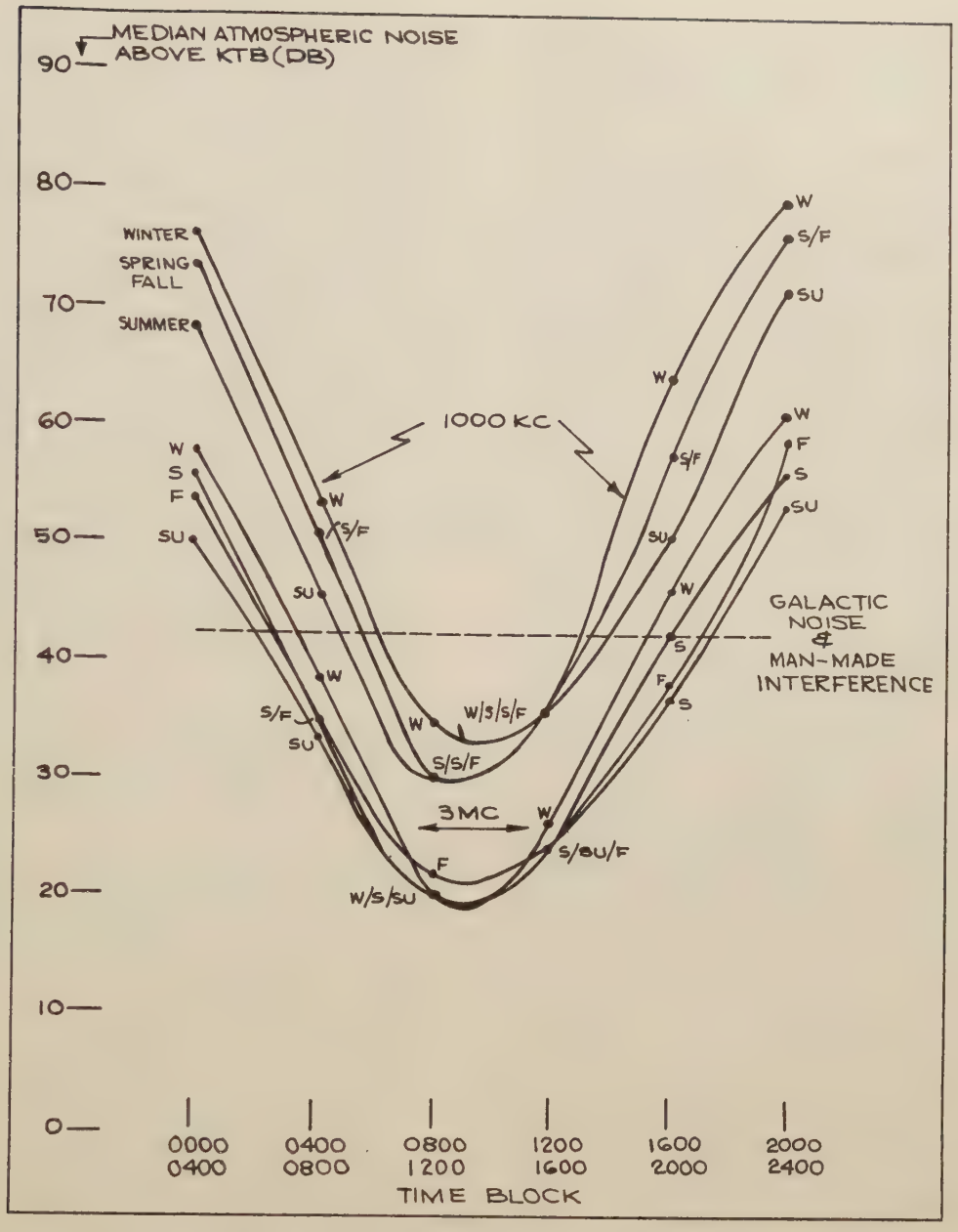


Fig. 5 - Seasonal noise values, noise grade 2½.

noise, to service during just those periods of the day when the noise will be at least 20 db below the desired operating level. Another form of interference which must be considered is the anticipated ionospheric co-channel interference[4]. An examination of ionospheric propagation charts shows that at 3 mc, for example, the interfering signal will be less than 200 microvolts per meter 10% of the nights, when radiated from a 1 kilowatt transmitter 200 or more miles away.

In order to know the transmitter power required, we will now have to calculate the net system loss[3]. The information required is detailed in Figure 6. In the medium frequency range, the initial transmission loss for distance, frequency, and antenna launching loss can be determined from the formula given which includes the transmitting antenna gain or loss and the loop antenna loss. In the medium frequency range, maximum potential gain of a vertical antenna will be obtained with a tower which is .64 of a wavelength in height. Approximately 6 db gain over a dipole may be achieved with a practical design[5]. Additional loss must be allowed for in the deviation of the atmospheric noise from the median values given. A maximum deviation from the median value is 28 db one-half per cent of the time[3]. The overall allowance for noise in the calculation should then be either the carrier-to-noise ratio, atmospheric, galactic or man-made noise, whichever is greater. The final noise value required is the

R.F. bandwidth noise. In equation 2, the transmitter power in dbw required is that which is necessary to overcome the net system loss over the thermal noise in a band one cycle wide.

In proceeding with the VHF system analysis, we must recognize that some compromises will have to be made in the method of calculation of antenna gain, since the form factor of the antenna is a compromise determined by the unit's size and shape. Due to the changing environment of the antenna, the gain is not accurately predictable; however, it can be determined by field measurement methods. In order to do this, we must establish a reference signal which is based upon a barely detectable (i.e., 3 db signal-to-noise) audio output from a known R.F. input which is applied directly to the receiver input.

Figure 7 shows the means whereby a field measurement is made, with the necessary calculations required to determine gain. The first step is to measure the field intensity required to obtain the reference output, when wearing the receiver, by substituting the field intensity measuring set for the person and the receiver. These measurements should be made in an open field area to avoid standing waves and other undesirable reflections. Knowing the field intensity required to produce the known signal power at the input, we may now use Bullington's formula for power received by a matched antenna, in terms of antenna gain and the measured field intensity. Following the pattern established by our low frequency analysis, we can then establish the required carrier-to-noise ratio from the power input needed for 20 db quieting relative to the thermal noise

$$L_t \text{ (TRANSMISSION LOSS)} = 20\log d + 20\log f + 36.58 - G_t - G_r \text{ DB} \quad (1)$$

d = DISTANCE IN MILES

f = FREQUENCY IN MEGACYCLES

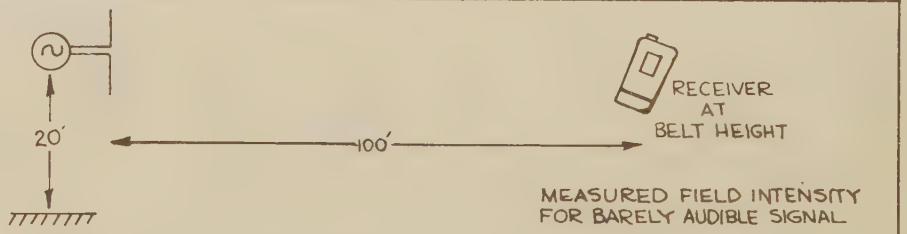
$$P_T = L_t + R + F + B - 204 \text{ DBW} \quad (2)$$

R = ALLOWANCE FOR RELIABILITY OVER 50% MEDIAN

F = C/N OR ATMOSPHERIC NOISE

B = RF BANDWIDTH

Fig. 6 - Derivation of transmitter power.



MEASURED FIELD INTENSITY FOR BARELY AUDIBLE SIGNAL

$$P_R \text{ (POWER DELIVERED BY MATCHING ANTENNA)} = \left(\frac{\mathcal{E}\lambda}{2\pi}\right)^2 \frac{G}{120} \quad (1)$$

$$G \text{ (GAIN OF ANTENNA)} = 10\log\left[120\, P_R \left(\frac{2\pi}{\mathcal{E}\lambda}\right)^2\right] \text{DB} \quad (2)$$

$\mathcal{E}$ = VOLTS/METER REQUIRED TO PRODUCE KNOWN POWER INPUT (P_R) DETERMINED BY MEASUREMENT OF BARELY AUDIBLE (3DB S/N) SIGNAL.

Fig. 7 - VHF antenna gain measurement.

and receiver noise combined. An examination of the anticipated galactic and man-made interference indicates that it will not be of sufficient significance to affect our operation. Random man-made interference averages for 20% of measurements made, approximately 5 db over 1 microvolt and galactic or cosmic noise can exceed the thermal noise threshold by 4 db in N. latitudes of 40^{03}. Considering the loss of the antenna, these values will not control the maximum sensitivity of the receiver. To determine the system gain required, we can evaluate the system loss following a similar process as used in the medium frequency study. The transmission loss, including distance, frequency and antenna launching loss, can be obtained from Bullington's propagation study. We may then arbitrarily select an antenna suitable for the application and use the gain which is known. The receiver antenna loss which we have obtained from our field measurement, which, for a typical pocket carried receiver, will be approximately 25 db, will complete the anticipated losses other than those variations in transmissions through building openings or due to standing waves. Typical building absorption losses may vary from 3 db near an opening to 17 db within the building in a typical three-story building. The losses will increase as we descend to the lower floors. At the second floor, it will vary from 8 to 34 db, and on the first floor, 12 to 50 db. Again, we should include the R.F. bandwidth noise. We can now calculate the total transmitter power required in the same manner which we used for the medium frequency.

Figure 8 summarizes the results and system analysis covering several frequencies from .3 mc to 150 mc. The analysis for 43 and 150 mc is limited to 1½ miles radius as a practical distance which a vehicle operator would required to extend his communications when on foot. The low frequency figures reflect the greater penetration power and lower antenna loss. If the pocket carried system is to be compatible, we compromise by the use of increased effective radiated power and reduced range of coverage. The analysis shows that a reasonable system may be designed, the coverage of which is as far as a person on foot would separate himself from the vehicle and permits the use of a standard mobile transmitter power output.

With the knowledge of the system requirements in hand, we can now examine a typical pocket carried receiver which has been designed to meet these requirements. Figure 9 is a block diagram of the RCA Micro-Miniature, Type CPC-R1, Receiver. The physical size of the receiver is 6½ inches by 2-3/4 inches wide, by 7/8 to 1 inch thick. The case is made of non-breakable plastic. All of the components are mounted to a mother board which is manufactured by an automatic process. The components, however, are hand-assembled, and after assembly, the wiring is dip soldered connected. The receiver is of modular construction, grouping significant related units. There are 11 modules providing the primary circuit functions. Each module also assembles its components on a printed circuit board. The receiver is of the double super-heterodyne type, using a separate crystal controlled oscillator as a source of injection voltage in the input mixer stage and a crystal controlled oscillating converter for the second conversion. There are 18 transistors contained in the unit.

Examining the block diagram, let us proceed in detail. The 152 mc signal is changed to 43.75 mc in the high I.F. system by means of the input mixer and oscillator. The 41.75 mc oscillating converter further reduces the frequency to 2 mc, where it is amplified in a single stage, preceding a 2 mc bandpass filter, after which three stages of amplification and limiting are applied prior to the discriminator. The last stage of low I.F. is saturated with noise. The output of the discriminator with 10 kc deviation is sufficient to drive the two stages of audio to provide 5 milliwatts of output, or operate a reed type selective calling device. The high frequency noise from the discriminator is fed to three stages of amplification for purpose of operating the squelch gate. This amount of amplification is required due to the low noise from the receiver. The squelch gate controls the audio output and also initiates the battery saver gate. The battery saver gating device is controlled by an asymmetrical multi-vibrator which operates on a .2 to 2-second cycle. During the .2 cycle, the gate is open and the battery positive terminal is connected to the receiver ground. During the 2-second interval, the gate is closed and the receiver is ungrounded. This provides approximately a 10 to 1 improvement in battery life. The model shown does not provide selective calling; however, the model which does, is quite similar circuit-wise, except that at the audio output, a tuned reed relay is used to initiate a buzzer alarm. This buzzer alarm is also equipped with a visual red flag to register a call in the event the wearer did not have the receiver on at the time the call was received. The reed relay decoder will provide up to 66 separate combinations. Pre-setting of the indicator flag will automatically re-wind the mechanical buzzer. However, the buzzer has a capacity of several dozen calls on one winding, depending upon how long the individual allows the signal to sound.

In conclusion, we will illustrate and describe present and potential applications of the unit. It is anticipated that the micro-miniature receiver will have many uses in the immediate future, such as military and civil defense, road building and construction, public utilities, telephone paging service, industrial and commercial firms and public safety services. It is presently being employed in this last category of public safety and law enforcement. This will be the most fertile field for its application since here is where the limitation of the mobile unit is most acutely felt. Considerable testing has been going on in Central Park of New York City. In this large area, the foot patrolman is entirely on his own. However, this day is coming to an end, for now the patrolman can be in constant

		⊢10 MI RADIUS⊣			⊢1.5M RADIUS⊣	
		300KC	1MC	3MC	43MC	150MC
RECEIVER ANTENNA LOSS	(DB)	11	17	14	35	25
RECEIVER INPUT NOISE	(DB)	12	12	12	6	19
RF BANDWIDTH	(KC)	6	3	3	30	30
AF BANDWIDTH	(KC)	3	1.5	1.5	3	3
AUDIO S/N	(DB)	20	10	10	20/Q	20/Q
MODULATION INDEX		.5	.9	.9	±10KC	±10KC
REQUIRED S/N	(DB)	69	50	40	10	21.7
REQUIRED RF GAIN	(DB)	27	49	58	97	79
PROPAGATION LOSS (10 MILES)	(DB)	46.2	56.8	66.2	83	83
ATMOSPHERIC NOISE, ETC	(DB)	95	80	60	14	4
RELIABILITY ALLOWANCE	(DB)	26	38	43	30	45
TRANSMITTING ANTENNA HEIGHT	(FT)	410	246	170	170	170
TRANSMITTING ANTENNA GAIN	(DB)	+0.6	+1.0	+0.8	-0.8	+5.15
TRANSMITTER POWER OUTPUT	(WATTS)	16	160	21	7.5	55

Fig. 8 - Typical system performance, 300 kc - 150 mc.

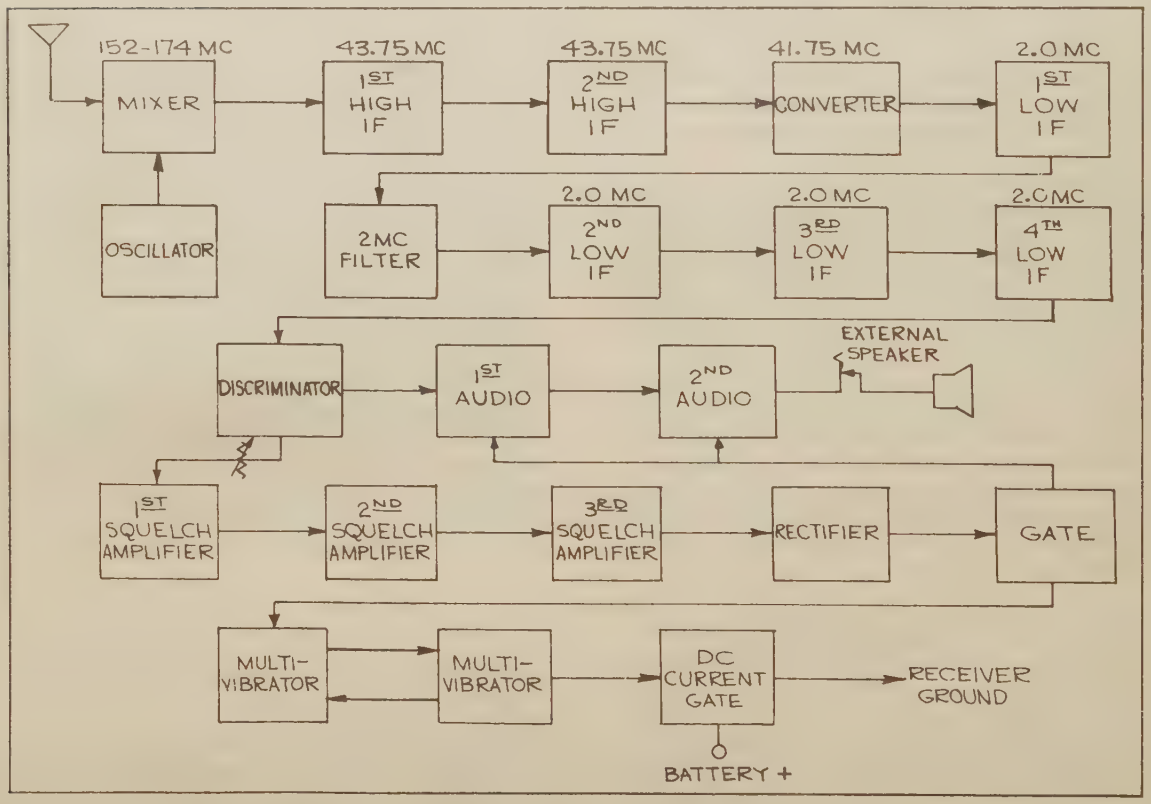


Fig. 9 - CPC-R1 receiver.

touch with his dispatching headquarters and be alerted to any emergency no matter where he may be within the park area. It is anticipated that the policeman will truly become a radio policeman always in touch with his headquarters, either through a radio controlled call box or through his mobile cruiser. The mobile cruiser can serve as an automatic repeater, thereby extending his call from the many inaccessible places which are found in and about a large metropolitan area, such as warehouse and dock areas and congested manufacturing districts. Other law enforcement

agencies, such as detectives and Government agencies, will find this unit an indispensable help in their law enforcement work.

Another highly useful field will be in the fire-fighting agencies. Here, the many diversified operations scattered over a very confused area, in which every situation is an emergency, the personal receiver will bring every man under the direct command of the Fire Chief. Hook and Ladder men at the top of their high ladders, and Pumper and Hose men working under very high noise conditions, and most important of all, the Searchers who go through the buildings looking for survivors and seeking out better ways to control the fire, will be more effectively directed.

The construction industry has a multiplicity of uses. The many equipment operators working in and about a large building can be coordinated far more effectively. Out on extended construction projects, such as highways and bridges, every man will be able to do the best possible job by being in constant touch with the project director.

The petroleum products and power utility transmission lines who have been the pioneers in the use of industrial communications will find this new tool a means of reducing cost and improving the overall operation. If anyone has ever worked with a field survey crew, he knows how helpful it would have been under many trying conditions, to be able to talk with the rod and chain man. The effectiveness of industrial plant protection will be enhanced tremendously, keeping the security guards in constant touch with their headquarters, and also maintaining constant communication with key personnel. Material handling machinery will be more effectively expedited than it is now with lower power industrial equipment. The safety personnel in large industrial operations will find this unit will take care of many difficult problems. The trans-continental transportation systems will also find this a useful tool. Railroads use the unit in handling cars in freight yards and car loading humps and providing individual communication between members of train crews. This unit can also be effectively applied to subway operations, allowing the platform conductor to keep in touch with the train crew going through the station. Already, the airline companies are examining the unit and testing it out for more effective supervision of the ground crews. Anyone who has used aircraft transportation recognizes that this is an operation that requires a great deal of coordination of effort.

Another field in which this unit will find much use will be in those areas of dispersed operation, such as motion picture crews in the field and large conventions which require many unusual problems to be solved on the spot. At the recent Indianapolis race, these units were used to effectively coordinate all of the cameramen from a common observation point.

Other types of field operations which will find use for this unit will be oil, mining and geological survey operations and other types of exploratory activities. The most important application will be search parties looking for lost people in difficult or inaccessible country. One of the first applications of this type of equipment on the lower frequencies has been in hospital paging. This relieves the patient of the aggravating constant "Calling Dr. Smith, Calling Dr. Smith". In military and civil disaster alerts, when normal communications may have completely failed, this unit will come into its day of saving many lives and property. Many manufacturing operations, as well as chemical and materials research operations, require a wide-spread installation, with many personnel moving and about buildings. The use of the personal paging receiver has been explored in this regard.

Last, but certainly not least, is the extension of the common carrier communications system to the individual. It can be expected that a day will come when an individual will be born with an assigned telephone number which he will carry with him for the rest of his life, for he will never be tied to a fixed telephone, but will be always in touch through his own personal private telephone.

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A COMPACT LOW-COST 150 MC MOBILE UNIT OF UNUSUAL DESIGN

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Montreal, Canada

Summary -- A VHF Mobile Unit is described which is one third the weight and employs 35 per cent less tubes than conventional units. The equipment meets current Canadian and U. S. Specifications, is rated at 10 watts rf output and has a sensitivity under 0.5 mv.

Compactness has been gained by the use of printed components, front-mounting and considerable simplification of the detection and modulation circuits.

The frequency multiplication factor of the transmitter is 4, which considerably reduces the number of spurious emissions.

Design Background

In analyzing the cost structure of a conventional 25 watt mobile unit, in 1955, we found that about 20% of the manufacturing cost was due to the remote-control features; viz., external cable harness, loudspeaker case, control head, etc. These items are required because of the need to mount the unit in the trunk, due to its bulk and weight.

A look at the production aspects of this mobile unit revealed two further facts:

1. Inter-chassis plugs and wiring added to the size and complexity, and,

2. The depth of the chassis and the general use of shielding partitions added significantly to the wiring and assembly time.

In Europe, it has been customary to mount the mobile unit in a single housing beneath the vehicle's instrument panel. Such a unit removes much of the bulk, weight and complexity of the trunk-mount unit, in common use in North America.

It was therefore decided to attempt to design a unit without remote control facilities, with few non-functional components and having minimum weight and bulk, without resorting to special miniaturized components and techniques, but with sufficient transmitter power to supply the coverage demanded in Canada and the United States.

These decisions resulted in a unit of small dimensions, weighing only 15½ lbs, of which 5 lbs are due to the power-transformer. This latter figure was made necessary by the decision to rate the transmitter at 10 watts output. (See Fig. 1.)

Mechanical Construction

The chassis is spot-welded into a single unit with a reinforcing step to the rear of the power supply section. A dished panel carries an anodized frame and the front escutcheon. The rear pillars serve to position the unit in the case and as battery contact supports, as shown in Fig. 2.

The top view of the complete unit shows the space utilization, and the problems that had to be resolved, particularly in the power-supply area, to enable parts to be replaced simply. The center of gravity was located well forward so that only a light rear mounting bracket would be required.

The under-chassis view, in Fig. 3, shows the relative freedom from shields. The rolled chassis edge provides some thermal contact with the case.

Fig. 1 - The complete mobile unit from microphone to antenna.

Crowding of parts has been reduced by employing eight printed components located on top of the chassis. These replace 44 conventional components in the I.F. and A.F. portions of the unit.

All coils, except those in the final transmitter stages, are of the lock-in type, employing threaded slugs which may be tuned from top or bottom of the chassis. Most of these coils, except receiver I.F. transformers, contain one metal slug and one powdered iron slug, permitting band coverage without the necessity for tap adjustments, etc.

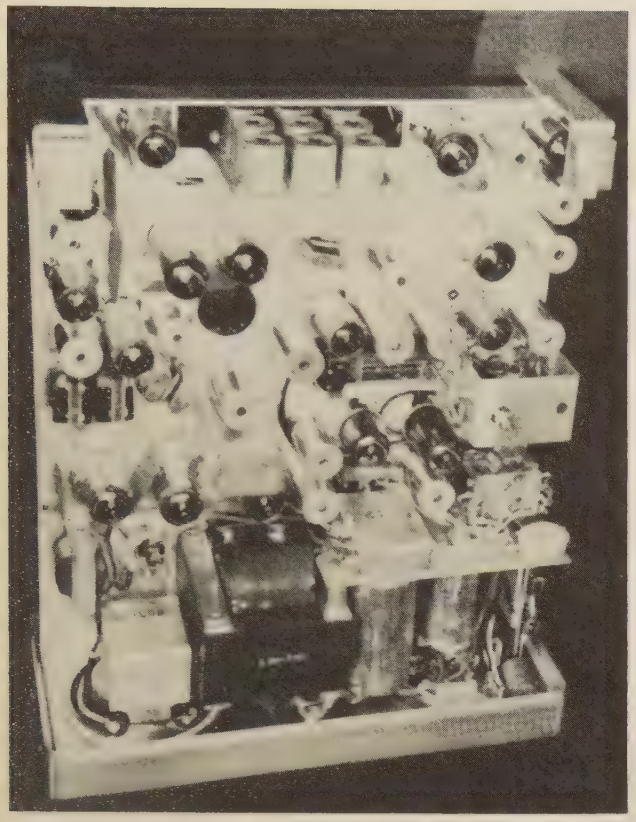

Fig. 2 - View of the top of the chassis.

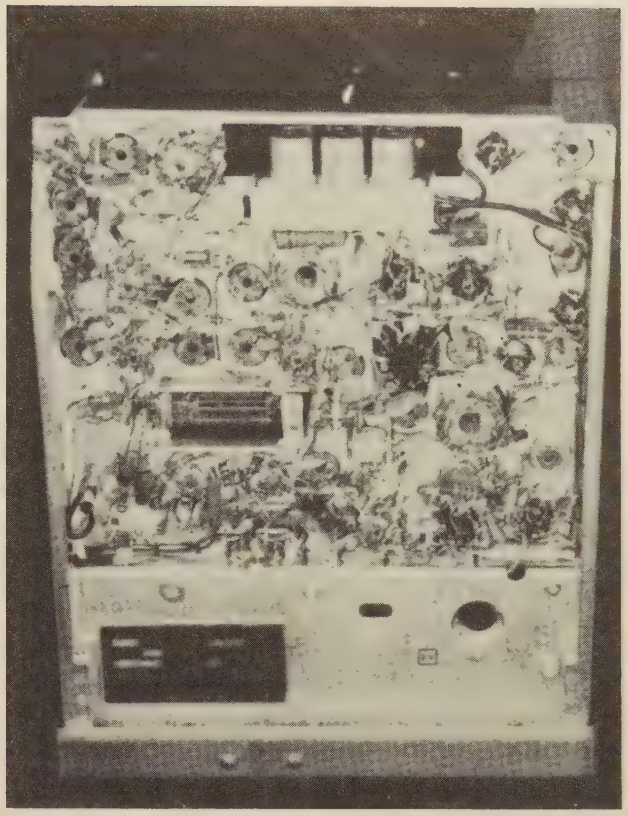

Fig. 3 - View of the bottom of the chassis.

Heating was expected to be a problem in such a small unit. This was offset by thermal contact between the chassis and case, and by punching slots in the sides and top of the case to permit efficient convection cooling. The chassis temperature rise is about 21°C in the receive condition, and remains remarkably constant when transmitting up to 1 minute in 5. This is probably due to the method used to cool the bulb of the P.A. tube, without transferring the heat to the chassis.

The complete circuit diagram of the unit is shown in Fig. 4.

Receiver Circuitry

The R.F. Amplifiers are quite conventional in most respects. The decision to use 6BC5 tubes instead of 6AK5's was made due to their reduced cost and longer life expectancy. The input loading and gain of the 6BC5 is somewhat inferior to the 6AK5, but these factors were offset in this design by using two R.F. amplifiers. This adds to the gain reserve of the receiver and had no negative effect upon the sensitivity. This indicates that the noise figure of the tubes was not a limiting factor in this case.

A considerable reduction of components was achieved by using a third overtone crystal oscillator. By starting at 48 to 55 mc. and tripling in the oscillator plate circuit, about 0.5 volts of drive can be obtained at the mixer cathode.

The 6U8A triode performs well as a mixer and combining the oscillator and mixer in the same envelope has had no harmful effects.

The first I.F. amplifier is designed for high stability rather than gain. The High-C circuits also permit the use of single layer I F. coils. The second oscillator-mixer utilizes the 6U8A's pin arrangement to provide internal coupling, the internal C being about 3 MMF between pins 1 and 2.

A 9-section 2nd I.F. filter is used to supply sufficient adjacent channel selectivity for spacings of 60 kc. The filter assembly may be changed for a 12-section filter, for 30 kc. channeling, without realigning the receiver.

The 2nd I.F. amplifiers show a small-signal gain of about 115 db overall. Low-Q coupling elements are employed so as not to excessively sharpen the nose of the I.F. frequency-response characteristic. Note that metering and decoupling functions are performed by three identical printed components, PC101, 102 and 103.

A significant improvement has been made in the detector - A.F. area. It is customary to employ one or two limiter tubes, a discriminator, two A.F. amplifiers and two squelch amplifiers, or about 5 or 6 tubes in all. This receiver has been greatly simplified by employing the 12BN6 gated-beam tube as a combined limiter-discriminator.

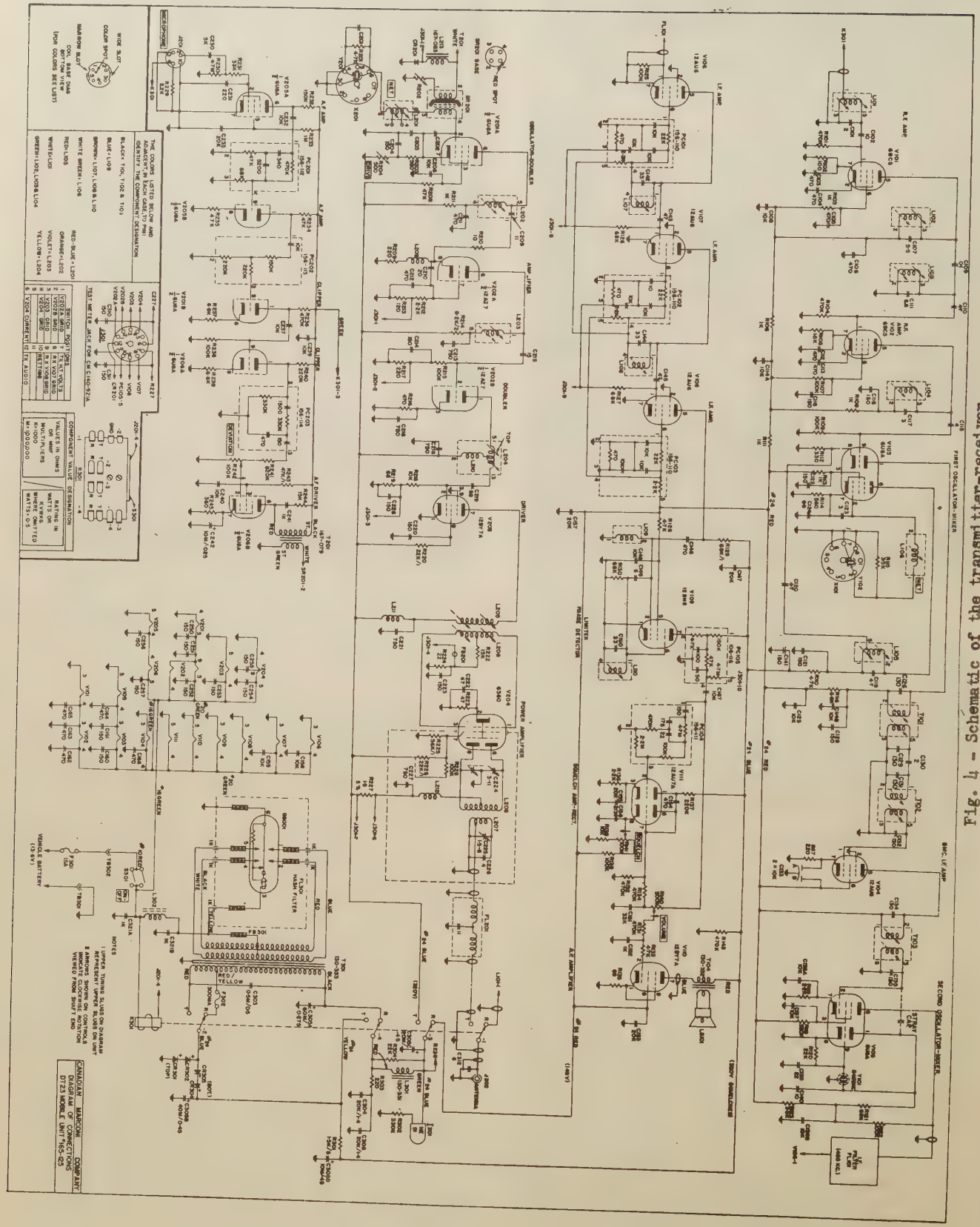

Fig. 4 - Schematic of the transmitter-receiver.

This circuit will be familiar to many due to its use in some TV receivers. Due to the large signal available however, no cathode balancing control is necessary. The A.F. recovery from this circuit is unusually high, being about 25 volts before de-emphasis with 10 kc deviation. Limiting action, A.M. rejection and harmonic distortion of this circuit were found to be completely comparable to a conventional limiter and Foster-Seeley discriminator of the type found in many present day mobile units.

A detailed comparison of these circuits may be found in the literature, although the figures quoted are for a frequency of 10.5 Mc.[1]

Due to the high output of V109, the phase detector, simplification of both squelch and A.F. amplifier circuits was possible. The squelch amplifier, V111, is fed via filter, PC104, which accepts the noise spectrum between 4 and 20 kc. The level is sufficient to require only one low Mu triode amplifier, the second section of this tube performs as a noise rectifier.

The 12BY7A was chosen over the customary 6AQ5 as an A.F. power-amplifier for two reasons:- 1) its trans-conductance is 4 times as high and 2) its cut-off bias is one fourth. This permits the tube to be driven easily with the output available directly from the detector, thus saving a stage. The lower cut-off requirement permits the A.F. stage to be biased off by the squelch circuit, resulting in nearly 1 ampere less battery drain at 12 volts.

The net improvement in this area was therefore the removal of two or three tubes and their components, but without having appreciably altered the performance of the receiver.

The Technical Specification of the receiver shows that it is comparable to present standards. The spurious responses between -85 and -100 db are basically only four. These are respectively half and twice the I.F. frequencies removed from signal frequency.

This spurious response rejection is primarily due to the large difference in frequency between the first and second local oscillator. The need for shields was practically eliminated by careful parts layout and by keeping components fairly close to the chassis.

Frequency stability can be improved by using a crystal oven, or a first oscillator crystal made to a tighter specification. This is not necessary in this model of theDT23 Mobile Unit, as it is designed to operate at 60 Kc channel spacing, and has a nose bandwidth of 34 Kc.

The 3½ inch loudspeaker has a response curve which attenuates frequencies outside the range 300 to 3000 cycles. This, in conjunction with 2 watts of available power, provides a very intelligible signal.

Transmitter Circuitry

It has become quite apparent, in the last few years, that spurious emissions from VHF transmitters can cause severe interference to communications systems, and to TV receivers. Many of these problems arise even though the particular emission is within the legal limit of -60 db down.

For example an off-channel emission of 10 microwatts can develop a 2 microvolt signal at the antenna terminal of a mobile receiver located one mile away.

Conventional mobile-type transmitters usually employ frequency multiplications of 18 to 36, between the oscillator and the antenna. In the latter case and at 162 mc, this means that the oscillator is operating at 4.5 mc. The transmitter is dependent upon the selectivity of its tuning apparatus, to avoid radiating on all integral multiples of 4.5 mc, certainly up to 1000 megacycles.

A practical improvement can be achieved by operating the oscillator in the VHF range, but this rules out the use of the simple phase-modulation system as we now know it, due to the inherent limits on deviation at low audio frequencies.

The DT23 employs a third overtone crystal, operating between 38 and 43 mc, the screen grid of V201A serving as a virtual plate in a Colpitts circuit. L201 and the RF winding of SR201 together with the grid-to-ground capacitance, form an "L" network which transforms the relatively low crystal impedance to a value more acceptable to the tube.

L201 is employed to adjust the crystal to exact operating frequency. The plate circuit is tuned to twice crystal frequency to reduce the effect of succeeding stages influencing the behaviour of the crystal.

Modulation is obtained by means of the saturable reactor, SR201, the R.F. inductance of which varies about a value fixed by a permanent magnet's bias and in proportion to the audio current flowing through its control winding. This produces proportional changes of frequency in the crystal circuit, upon which there are less fundamental limits than in the case of the phase-modulator.[2]

Due to the inherent non-linearity of the crystal's frequency vs inductance characteristic, however, such a modulator exhibits rather high intermodulation distortion and apparent shift of the mean transmitted frequency, during modulation. This has been overcome by employing a carrier correction circuit consisting of L213, CR201 and R202. The single-plate selenium diode introduces an opposite non-linearity, which is balanced by factory adjustment of the resistor R. This circuit reduces inter-modulation to between -12

and -25 db, which is more than sufficient in speech range equipment.

A high-impedance dynamic microphone is used, which has a rapid decrease in sensitivity below 300 cycles, to minimize noise pick-up from the vehicle. This connects to V205, which is a two stage speech amplifier. This is followed by a double-triode peak clipper circuit. V206B supplies sufficient A.F. power to operate the saturable reactor. The primary of the coupling transformer T201 is resonated near 3000 cycles, to produce a very rapid attenuation at higher audio frequencies, to minimize sideband splatter.

Simple interstage coupling methods were employed in the R.F. stages of the transmitter, due to the reduced need for selectivity. The main functions performed here being those of multiplying the frequency by 2 and making available about 1.5 watts of power to the P.A. stage. V203 is operated near Class C conditions.

The compactness of the overall unit is due largely to the 6360 dual-tetrode, employed as a power amplifier. This tube is very inexpensive and behaves reliably if it is well driven and if its pin and bulb temperature ratings are carefully observed. These are 120° and 225°C respectively. It has been possible to maintain output figures between 10 and 14 watts, on a production basis, at a plate efficiency of about 53%. The ICAS maximum plate dissipation rating for this tube is 14 watts.

The modulation characteristics of the unit have been corrected to the industry standard for phase-modulation, although the modulation system employed is basically FM and could, if necessary, supply full deviation down to sub-audio frequencies. The response curve is shown in Fig. 5.

The advantages of the high oscillator frequency can be seen in the Spurious Emission Chart of Fig. 5. Only one appreciable emission is detectible below operating frequency. No in-band spurious emission can occur, as the nearest ones would be located at 129 and 190 mc.

This method of transmitter design and its lower number of spurious emissions, will help materially in the reduction of interference caused by mobile units. Since the remaining spurious emissions are at least ±25% removed from

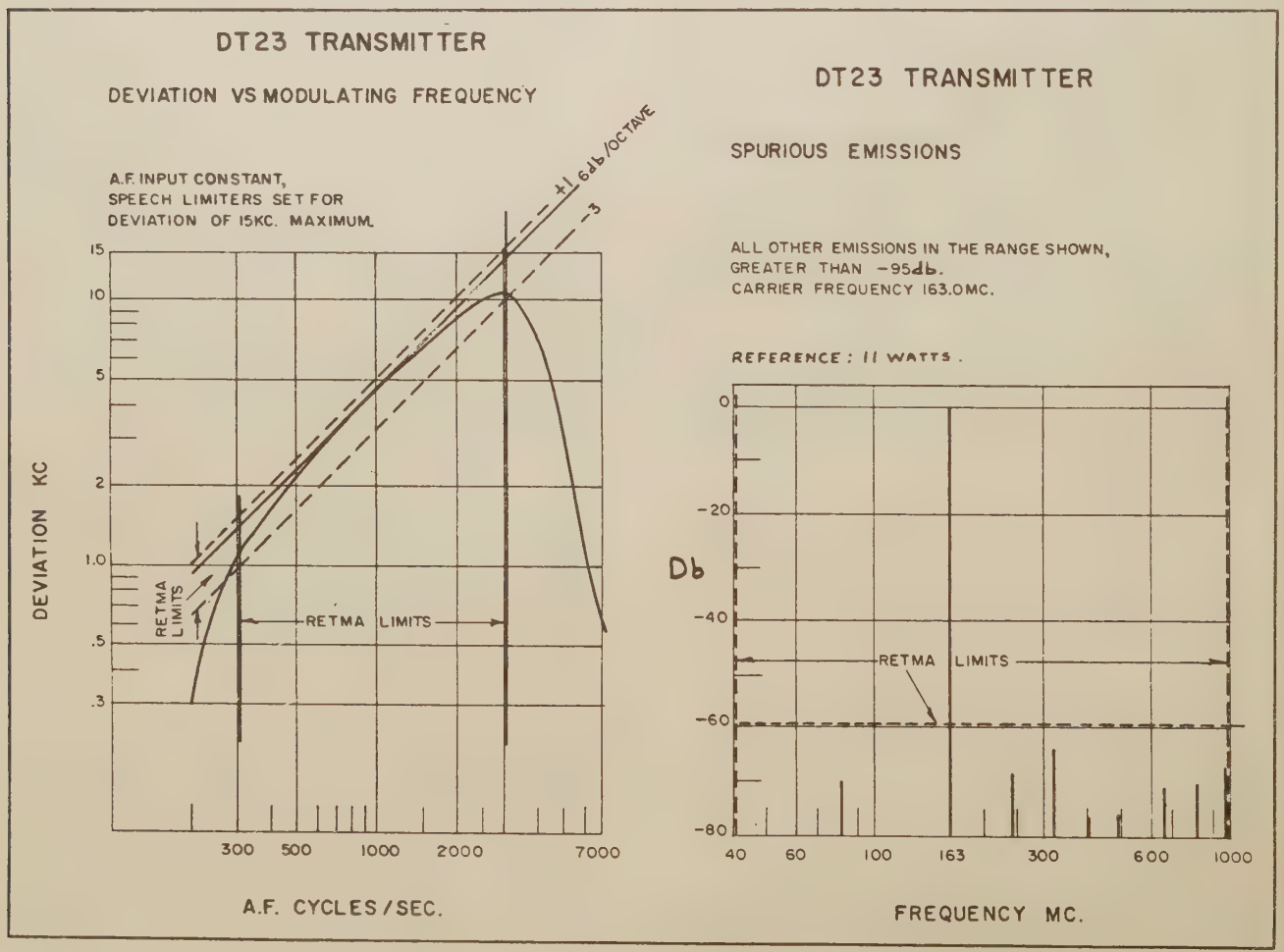

Fig. 5

the operating frequency, simple filters may be employed to further reduce them, should this ever become necessary. FL201 is a low pass filter intended to produce a margin of safety by reducing harmonics of tne carrier frequency by an additional 20 db.

The Power Supply

The power supply consists of a voltage-doubler arranged for maximum utilization of components. Although the transistor may soon excel in the inverter field, it was felt that a unit in the 10 watt class could take good advantage of the low replacement cost and fair life characteristics of the dual-interrupter vibrator. Silicon rectifiers help to reduce bulk, contribute to an overall conversion efficiency of about 63%, and show a favourable life expectancy, even at high operating temperatures.

Conclusions

The DT23 mobile unit, due to its small size and low battery drain, will find new applications where these factors are important. Due to the reduction in spurious emissions, which has been achieved, some contribution has been made towards the overall reduction of mutual interference in the HF and VHF portions of the spectrum.

New circuit techniques have reduced the number of tubes by about 35%, compared to conventional units.

Field reports, to date, are very encouraging and indicate that the concepts embodied in this unit may have some lasting effect upon design trends in the industry.

References:

1. "Frequency Modulation Engineering", Tibbs and Johnstone; John Wiley, 1956.

2. "A High-Performance Mobile Unit for 450 Mc", Robbins and Ayer; IRE Transactions, PGVC-6, July 1956.

APPLICATION OF SINGLE SIDEBAND FOR MOBILE COMMUNICATION

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This paper may be considered to be a sequel of the paper which Mr. Magnuski and myself presented last year before the PGVC in Detroit. The previous paper entitled, "Comparison of SSB and FM for VHF Mobile Service" considered such factors as a) the same FM and SSB equipment size b) signal to noise ratios c) transmitter power d) speech processing e) preemphasis and improvement factors and f) bandwidth. Also it was mentioned that a) a good AGC to combat flutter was needed, b) a good solution to ignition noise problems was required c) a solution to the squelch problem was needed and d) that cost was an important factor.

It is our intention in this paper to report on our progress and system approach since last year, and primarily to discuss the problems which had been pointed out last year. Time will not permit a discussion of such factors as transmitter noise and intermodulation, but perhaps a later discussion will.

Before discussing how Single Sideband (SSB) techniques can be applied to mobile communications, certain characteristics of mobile radio systems, which make it different from other radio or telephone communication systems will be briefly reviewed.

It is necessary to keep it in mind that mobile communications are concerned with complete coverage of a local area irrespective of obstructions contained therein; that long range interferences such as skip are undesirable and finally good communication should be obtained while the vehicles are in motion. Additionally, operation should be achieved without interference between similar systems operating simultaneously in the same area but on adjacent frequencies. Let us consider briefly some of these points.

1. The Frequency Band

   The VHF band around 150 MC is often considered the best for general mobile application. Lower frequencies around 40 MC are extensively used for large ground coverage in rural systems but they quite often suffer from interference between widely separated systems due to skip propagation. Still lower frequencies would require large, impractical antennas for efficient operation. Higher frequencies, 450 MC and even 950 MC can be used successfully for urban systems. These VHF frequencies will require a high order of frequency stability which excludes certain types of SSB systems as will be described later. Also in fast moving vehicles such as airplanes, the Doppler effect is very pronounced thereby eliminating still other SSB systems from consideration.

2. Variations of Signal Strength.

   The mobile unit has to receive equally well, very strong signals and very weak ones. The range of signals may exceed 100 db. In addition the vehicle may have to receive a weak signal from a distant transmitter while being in close vicinity to other transmitters working on other channels. This situation not only puts stringent requirements on selectivity, intermodulation and desensitizing characteristics of the receiver, but also on transmitter noise and modulation splatter. Another problem is the rapid variation of signal strength, (flutter) when a vehicle is in motion due to reflection and standing wave pattern. This imposes stringent requirement on the AGC circuit in SSB systems while it is solved by the use of limiters in the FM case.

3. Impulse Noise

   The mobile receiver is usually exposed to a considerable amount of ignition noise and other impulse noises either from its own engine or from other vehicles. Mobile receivers will have to be relatively insensitive to such noise or will have to have additional protective circuitry to combat it.

4. Operation with Multiple Transmitters and Receivers

   In mobile systems usually several transmitters and receivers are involved. Different system transmitters have to be received without delay and without tuning the receiver for best reception. I am referring here to the so called "voice clarifier knob" which is often used in SSB systems operating on low frequencies. Also an efficient squelch system is necessary which will not limit the receiver sensitivity and which will protect the operator from the noise which is present when a very weak or no signal is present. The operator is usually the driver of the vehicle and can only operate a simple push to talk button; all the rest has to be automatic. In this respect the mobile units should be as simple to operate as a telephone.

5. Reliability and Ruggedness

Mobile equipment has to operate over wide range of temperature and humidity and has to be as simple and rugged as possible. It has to withstand shocks and vibration and provide reliable service with minimum maintenance. Also the available primary power is usually limited and the efficiency of the equipment should be high to avoid overloading of the car battery if such is involved. Reference is made here to the equipment with very high frequency stability, requiring precision ovens which may be obtained in the lab, but may not be practical in the field.

To fulfill all the requirements just discussed at first AM was tried, but it was soon found that FM with its improved S/N ratio, and its insensitivity to impulsive noise was very well suited for mobile applications. For many years now FM has been used very successfully. Unfortunately, FM does not make the best utilization of the available frequency spectrum and so it is natural as more and more uses for mobile communications are found, that eventually severe crowding of the available spectrum would occur. This is the point we are approaching today, and some other type of communication must be used if we are to provide the necessary channel allocations. It is apparent that due to the expected improvement in spectrum utilization by the use of SSB, its application to mobile vhf service would be desirable if it could be achieved. In the past decade, significant strides have been made in building oscillators of greater and greater stability, and improved methods of selecting out and regenerating a carrier immersed in noise are now available. These two factors have made it possible to consider and build SSB for VHF mobile applications. It is our contention that if SSB can be shown to perform a communication job equivalent to that of existing systems, then due to the vital importance of spectrum economy, single sideband will win out as the eventual system for communications in general and mobile applications in particular.

As is well known, the main deterent to the application of SSB to the vhf frequencies has been the problem of crystal-controlled oscillator frequency stability. At present, the best frequency stability of practical oscillators having oven-controlled crystals is approximately 2 parts per million over the temperature range -30°C and +85°C, and since there are two high-frequency oscillators in the transmitter-receiver combination, an SSB system can be expected to have an over-all frequency stability of around 4 parts per million. On the other hand, investigation has shown that a locally generated carrier in an SSB receiver must be within 50 cycles of the correct frequency to give the detected voice signal the proper tonal qualities. On the basis of the expected frequency stability, reinjection of a locally generated carrier in a VHF receiver is not feasible and a pilot carrier must be furnished by the transmitter.

Since the amount of sideband power available from the transmitter decreases rapidly as the carrier power is increased, the power of the pilot carrier must be held to minimum. This relationship is shown in Figure 1.

Motorola is currently experimenting with such systems, where the pilot carrier is reduced to a level 13 to 20 db below the peak power of the sideband and is continuously radiated with the sideband. Any system of communication which supplies the standard of coherence (carrier) at the detection point and does so without any frequency error may be called a synchronous system.

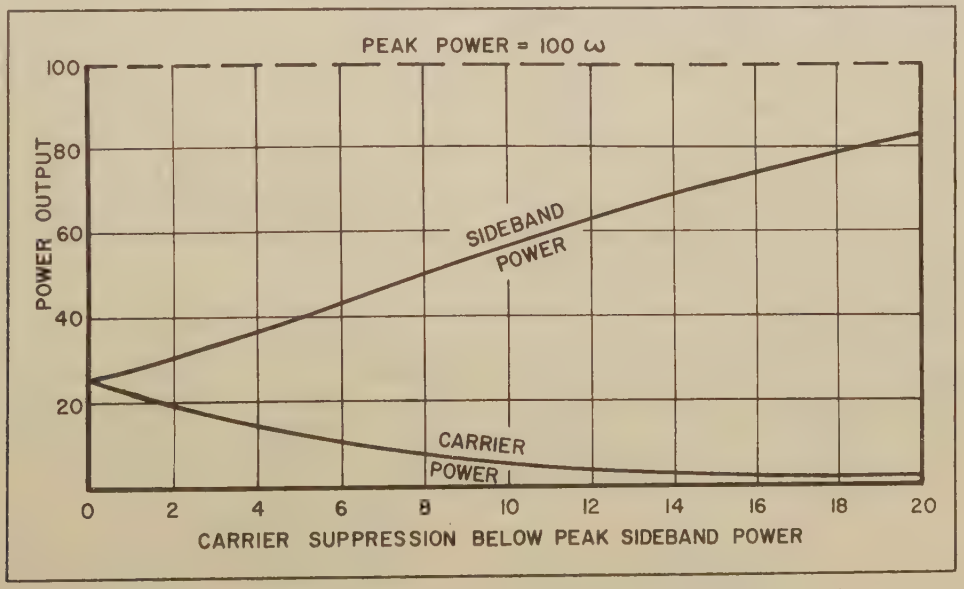

Fig. 1 - Variation of sideband power with carrier suppression (linear final-peak power limited).

For this reason the Motorola reduced carrier system when detected by a phase locking system is in fact a Synchronous system, i.e., - a Synchronous SSB system (SSSB).

Splatter

In designing an SSB transmitter, we have to remember that single sideband transmission inherently requires a linear relationship between the input voice signal and the rf output signal of the transmitter. Non-linearities in the transmitter can result in intermodulation between the carrier and the voice spectrum, and intermodulation between the voice spectrum components themselves. This can produce excessive modulation splatter of the transmitter into adjacent channels and may seriously curtail the spectrum utilization.

In Fig. 2 we see a transmitted r.f. spectrum from an SSB transmitter where no effort has been made to control linearity. The splatter components on either side of desired sidebands are clearly visible and seen to be some 36 to 40 db below the desired sideband peaks. Preliminary data on an SSB transmitter where some effort has been made

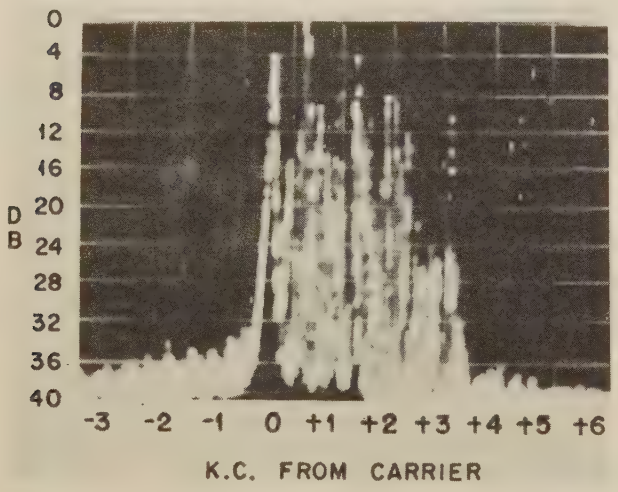

Fig. 2 - SSB spectrum output of final amplifier.

to control linearity shows that these splatter components can be reduced to some 65 db or better. It becomes clear that this serious problem of sideband splatter can be significantly improved upon to the point where it is becoming comparable to that of other types of modulation.

Synchronous Receiver

The block diagram of a synchronous receiver used for the experimental purposes is shown in Fig. 3. It is a dual conversion receiver and the stages prior to the highly selective 455 KC mechanical filter are identical with present production FM receiver.

The detection method used is the SSB receiver to separate the carrier from the sidebands is similar to the method used in color TV receivers to phase synchronize the reference oscillator to the short bursts of color carrier. As shown by the portion of the receiver block diagram enclosed in dotted lines, the carrier restoration system consists of a 455 KC oscillator which is phase locked to the incoming carrier signal. This is accomplished in the following manner. If the 455 KC local oscillator is not precisely at the same frequency as the nominal 455 KC incoming signal then a pulsating d.c. voltage appears at the output of the phase detector. The pulsing rate is at the difference frequency. This pulsing signal passes thru the low pass filter and by means of the reactance tube causes the 455 KC local oscillator to move to that new frequency where no pulsating d.c. (or error voltage) is present to cause the reactance tube to pull the local oscillator any further. Once the system is locked, however, a resultant d.c. voltage remains at the output of the phase detector. If the local oscillator was pulled only a small amount then only a small d.c. voltage appears, if, however the local oscillator was pulled by a large amount, then the resulting d.c. is larger. This d.c. is due to the static phase difference between the incoming signal and the locked local oscillator.

When sidebands are present, they try to cause the local oscillator to unlock from the pilot carrier and lock on themselves. However, due to the large number of them and their transient nature they cannot cause unlocking. They do, however, momentarily add to the carrier causing instantaneous new phase relationships to occur in the phase detector. The phase detector senses this incoming signal phase change and yields a varying d.c. output at the same rate as these changes occur. Therefore, the output of the phase detector contains frequency components which occur at the same rate as the sidebands (which are trying to unlock the system). It becomes clear then, that in the presence of audio sidebands, audio components appear at the output of the phase detector. Hence, once a phase locking system is decided upon the audio detecting is obtained automatically without additional circuitry. Also it is worth pointing out that once the system is locked the low pass filter which starts cutting off at approximately one cycle will also cause discrimination against the sidebands which are trying to unlock the system. Also we should keep in mind that the carrier is there constantly and the carrier restortion system actually integrates it due to its steady nature.

Impulse Noise

In FM systems, impulse noise is generally not a severe problem because the impulse energy in the r.f. modulation bandwidth has to be larger than that of the desired carrier in order to cause a large disturbance (often referred to as a 'POP'). That is to say the impulse noise must be large enough to momentarily capture the receiver and hence cause momentary large detectible phase changes. Amplitude changes in FM which are smaller than the carrier amplitude and wiped out in the limiters and are therefore of little consequence.

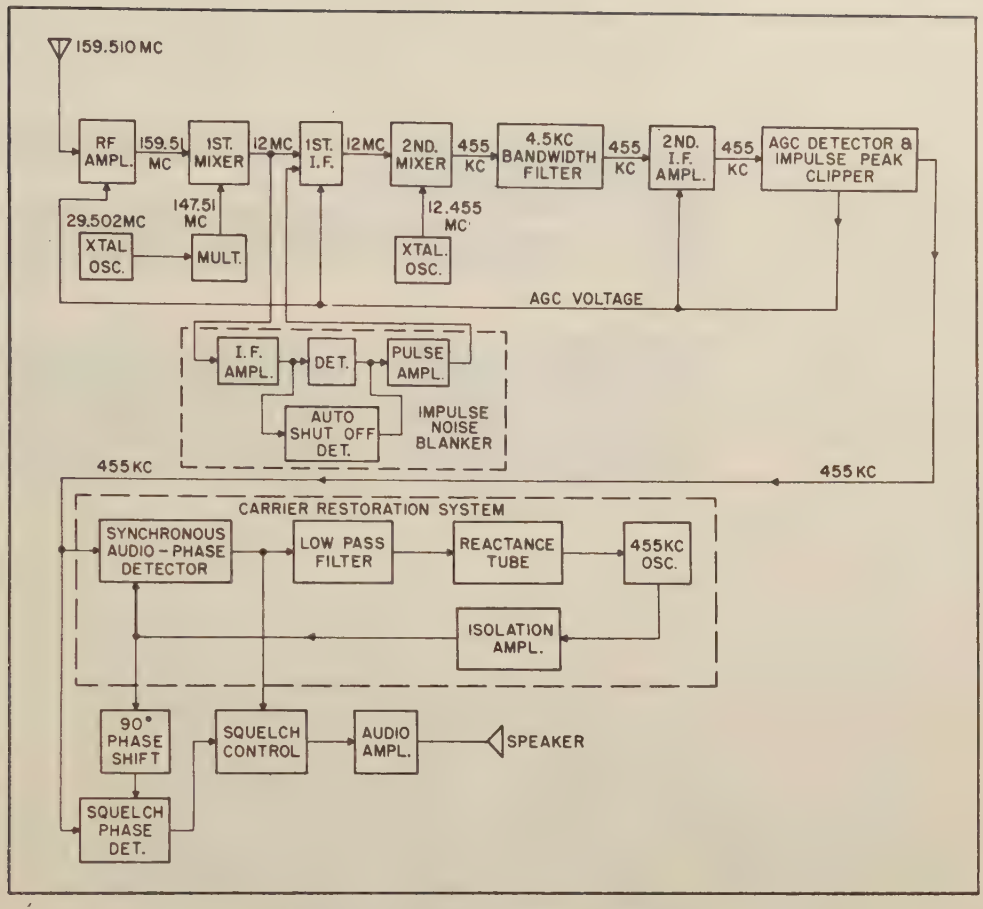

Fig. 3 - Single sideband receiver.

In AM or SSB the above comments do not apply because both AM and SSB receivers respond to amplitude variations at the input terminals of the receiver. Unless special techniques are employed, the amplitude disturbances at the output of these receivers, resulting from impulse noise, will be directly proportional to the size of the impulse noise at the receiver terminals. Of course, this is true only up to the point where limiting of the disturbance occurs at the grid of and IF amplifier stage. When the desired signal is very low in amplitude, a large ignition disturbance at the receiver input terminals can result in an audio disturbance which is considerably larger than the desired voice signal.

Besides the AM receiver being fundamentally responsive to these amplitude variations, ignition noise is more severe than in FM systems because they are inherently more narrow-band and hence stretch (or ring) the impulse for a longer period. Also in AM type receivers the impulsive disturbance may be stretched by the AGC circuitry.

To obtain performance comparable to FM, it was necessary to equip the receiver with a Motorola developed impulse 'noise blanker' which is in effect a side channel operating at the high IF frequency. This side channel detects the presence of an impulse and after suitable amplification gates the receiver IF off during the disturbance. This blanker takes advantage of the difference in frequency and amplitude content of the pulse at the sampling point. With the aid of the blanker, SSB receivers can perform as well on impulse noise disturbances as existing FM equipment. Fig. 3 shows the block diagram of such a side channel.

To demonstrate how effective this blanker can be we need only to refer to Fig. 4 which is self explanatory. With the blanker 'on' the impulsive ring in the IF amplifier is removed, but instead of a hole in the signal appearing, the filter actually holds the preceeding desired energy until new desired energy appears, hence only a slight dip in the r.f. energy is observed. The actual audio disturbance is tremendously reduced as is evidenced by the 2 lower pictures. A tape will be played shortly to demonstrate the effectiveness of the blanker in actual practice.

The following tape is approximately $3\frac{1}{2}$ minutes long and will demonstrate the following items.

a) Listening test of FM and SSB for comparative purposes.
b) The ignition blanker 'in' and 'out' of operation.
c) Squelch operation.

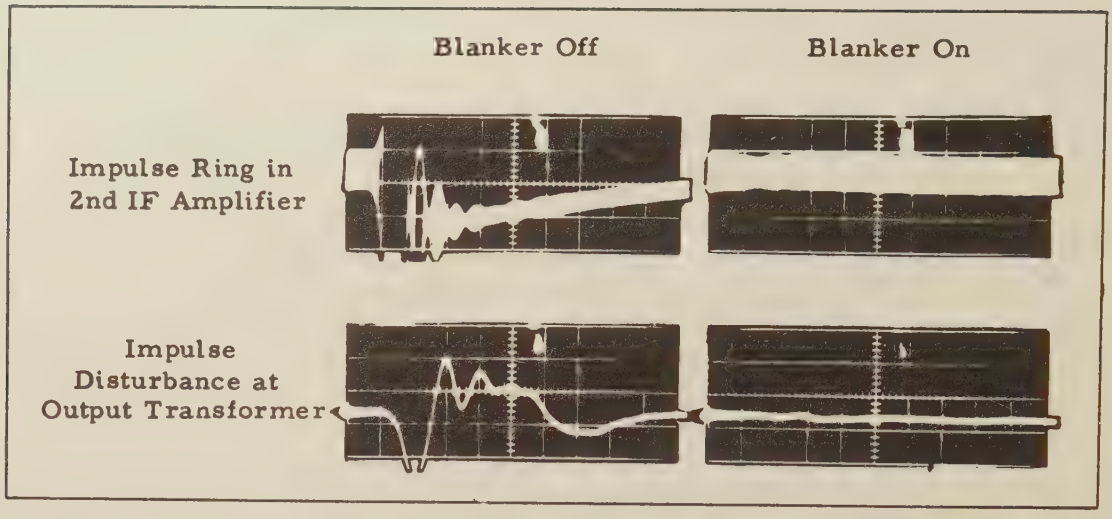

Fig. 4 - Ignition noise blanker operation in SSSB receiver, sweep speed = 500 μsec/cm.

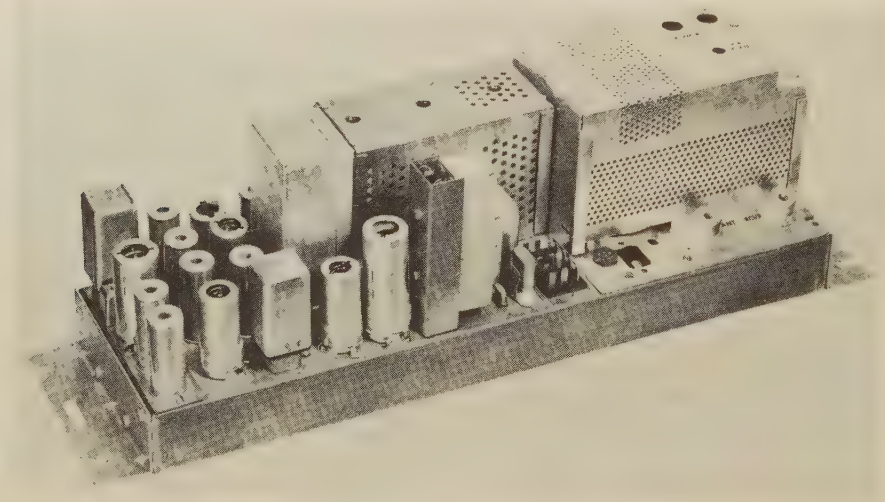

Fig. 5 - Single sideband transmitter.

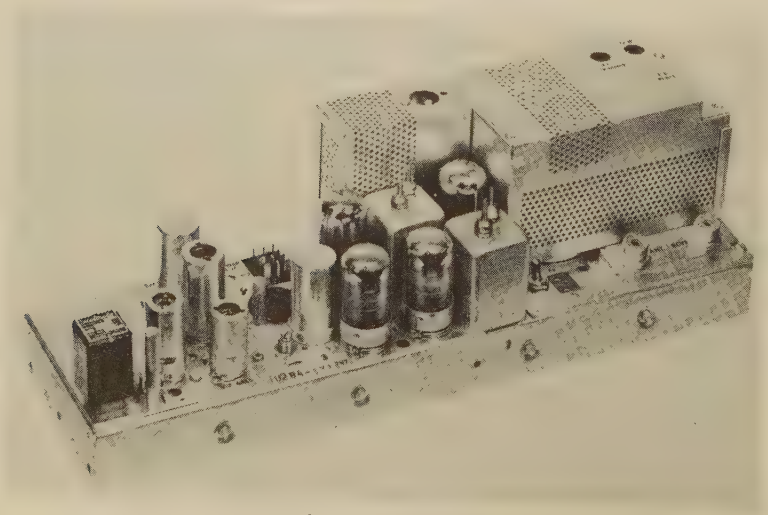

Fig. 6 - FM transmitter.

d) Listening test with the receiver unlocked and slightly off frequency and then with the receiver automatically locked or synchronized.

The Tape Is Played.

The tape you have just heard demonstrates the blanker operation, the receiver locking characteristics of this experimental system and the squelch operation.

Squelch

Up to now I have not mentioned the importance of the squelch circuitry, let alone how it operates and why it is as effective as you just heard by listening to the tape.

To begin with when no signal is being received or a weak unreadable signal is being received, it is highly desired that the receiver be muted so that the high noise output of receiver will not disturb or detract the listener. Under these conditions the noise is bound to be high because the receiver will be operating at maximum gain since no AGC voltage will be present. The process of muting or squelching the receiver under weak signal conditions then becomes important from a listener fatigue and disturbance point of view.

If we again refer to Fig. 3, our receiver block diagram, we can readily recognize a 90° phase shifter block and a squelch phase detector block in the lower left hand side of the figure. These two circuits are all that are required to be added to the receiver to obtain an excellent squelch operation. These two circuits contain no active elements and a minimum number of components. When the d.c. output of audio phase detector is nominally at zero volts, the output of the squelch phase detector is at a high d.c. voltage (in excess of 20 volts). The two outputs are a function of sin θ for the audio phase detector and cos θ for the squelch phase detector. It is clearly the 90° phase shifter which accomplishes this change of output from sin θ to cos θ . The valve of θ is usually close to zero degrees. The large d.c. output of this squelch phase detector when a signal strong enough to lock the receiver appears is sufficient information to unsquelch the squelch control circuit. Therefore once a phase locking receiver is decided upon the ability to obtain excellent squelch action is easily achieved.

AGC

The AGC circuits have to be designed very carefully and the AGC voltage of the receiver is derived from the combined carrier and sideband signal. Since the voice syllable rate and the flutter rate are in the same frequency range, there was a question as to the effect of a fast response AGC upon the intelligibility of the voice signal. Listening tests in the laboratory indicated little difference between a fast acting AGC and very slow acting AGC when receiving a voice signal. The presence of the carrier makes the AGC job easier.

Summary

In summarizing the above comments we may say that the following items are advantages of the Motorola Synchronous SSB system.

1. Less Frequency Stability Required Due To The Phase and Frequency Lock Characteristics.

2. Easily Moved Upward in Frequency Due To Phase Lock Ability.

3. Easy Squelch Control Due to Phase Locking.

4. Easy AGC Action Due to Pilot Carrier.

5. Transmits Selcal and Frequency Shift Telegraph Information.

6. Easy Compatability With AM.

7. More Voice Processing Possible Since No Frequency Distortion Exists.

8. Audio Detection is Automatic.

9. Locks Faster Than Most AFC Systems.

10. Doppler Shift Eliminated.

Of course not all of these advantages can be taken advantage of in any given situation. For example the elimination of doppler shift is of great importance in the aeronautical service but of little interest in mobile communications.

Recently Motorola has designed and constructed an experimental Base Station and mobile fleet of SSB equipments for the 150 mc. band. This coordinated group of vehicles is called a radio central, and its current application is for the military. The operating data and experience derived from this system along with the best experimental measurements today, show that 10 KC spacings between mobile equipments is achievable today even in the 150 mc. band.

As improved techniques become available and further improvement is made on the currently system limiting problems, such as transmitter noise, splatter receiver intermodulation, etc., it is expected that spacings of 5 KC between mobile stations will be achievable some time in the future.

Conclusion

1. SSSB can provide comparable performance as far as range is concerned, using equipment of the same size.

2. SSB equipment is somewhat more complex and perhaps more expensive, but will provide spectrum savings of an order of 2 or 3 times as compared to split channel FM Systems.

3. In strong signal areas, FM equipment will have somewhat better S/N ratio.

4. SSB equipment will consume less primary power as the consumption is function of speech loading.

5. Additional circuitry to combat ignition noise is required in SSB receivers.

6. SSB transmitters have to be carefully designed to be linear and avoid modulation splatter which has to be controlled to permit spectrum conservation.

The general conclusion is that the Synchronous Sideband System is well suitable for mobile service at VHF and it will provide more channels at the expense of somewhat more equipment complexity.

TRANSISTORIZED FREQUENCY REFERENCE AND CONTROL SYSTEM FOR 920 CHANNEL MILITARY VEHICULAR VHF-FM RECEIVER-TRANSMITTER

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Summary

Receiver and transmitter frequency control is accomplished by two phase comparison loops, The primary loop compares the phase of the receiver VFO with the output of a Crystal Reference System containing a total of 13 crystals and using three stages of interpolation to cover the required frequency range. The secondary loop, on transmit, uses the controlled receiver VFO for the sidestep function and a crystal stabilized reference oscillator, which is capable of being modulated, for phase comparison. The receiver-transmitter covers a range of 30-76 mc in two bands with 50 kc channel spacing. The control system is capable of handling ±400 kc VFO setting plus drift error from nominal frequency. It employes transistors throughout and is capable of operation over a temperature range of -55 to +85°C. Thermistors and block filters are used to achieve gain and bandwidth stability. Receiver spurious frequencies due to the control system are down 85 db or more. Transmitter spurious radiation due to the control system is down 85 db or more except for a few channels near the receiver i-f harmonic crossover frequencies, where the spurious radiation is down 75 db or more. High speed crystal switching has been achieved in the reference system allowing rapid, automatic change of channels. The receiver frequency control system occupies approximately 40 cubic inches and employs individually packaged printed circuit plug-in subassemblies. Total receiver and transmitter control system power drain is less than one watt.

The rapid advances in the techniques of modern warfare as well as the rapid means of transportation have created an urgent need for more channels of reliable communications. Since the frequency spectrum cannot be enlarged, one means of obtaining these channels of communications is to decrease the channel spacing. In order to accomplish this the frequency determining devices in the communications system must have greater and greater stability. In this paper the authors will discuss the systems used to stabilize the receiver and transmitter oscillator in the AN/VRC-12 equipment.

The AN/VRC-12 equipment is being developed on a U.S. Army Signal Corps contract for the Combat Area Branch of the Signal Corps Engineering Laboratories, Ft. Monmouth, New Jersey. This equipment is a transistorized military vehicular communications system capable of furnishing 920 channels of communication in the frequency range of 30 to 76 megacycles and operating from the 24 volt battery of the vehicle. The AN/VRC-12 is the first transistorized military vehicular system designed completely for 50 kc channel spacing. The system is intended to eventually replace the standardized series which has 100 kc channel spacing and requires three different receivers and transmitters to cover the 20 to 54 megacycle range.

For the VRC-12 equipment reliability and miniaturization are primary requirements for the frequency control devices as well as the entire system. Accordingly within the limit of the state of the art, solid state devices have been employed throughout the equipment design. In respect to the frequency control system and the use of transistors, experience gained on the R-442 and R-745 Receivers was invaluable. These receivers, developed by Crosley engineers, are forerunners to the present VRC-12 system.

Before we describe the frequency control in detail, it may be well to mention some of the requirements on the receiver and receiver-transmitter of the VRC-12. The receiver is required to have a sensitivity of 0.3 micro-volts for a 10 db signal plus noise to noise ratio and the spurious responses are to be down 85 db. The transmitter output requirement is 30 watts and all transmitted spurious frequencies are also to be down 85 db. The receiver-transmitter has provisions for ten preset channels and can be manually or automatically tuned. In the automatically tuned position a servo system is used to obtain the three second tuning requirement between any two preset channels. The preceding requirements are to be maintained under military environmental conditions which includes operation over an ambient temperature range of -40 to +65°C.

For a reliable 50 kc channel receiver-transmitter operating in the VHF band very stable oscillators are required. These oscillator frequencies can be derived by frequency synthesis techniques, which may lead to spurious problems, or by free running oscillators that are regulated by special control systems. We would like to elaborate on the latter method.

The term control implies a reference or standard, along with its conventional meaning of regulation, direction, or error correction. A frequency control system then could consist of the following:

1. Frequency standards, normally one or more quartz plates;

2. A means of detecting the error existing in the oscillator frequency;

3. Control circuit for correcting the existing errors.

These elements can be seen in Figure 1 which shows a block diagram of the major frequency determining components of the receiver-transmitter.

In this figure two frequency control loops are shown. The primary frequency control loop, called the Crystal Reference System (abbreviated CRS) is used for channel derivation and controlls the frequency of the receiver local oscillator within $\pm$ 3 kc of nominal channel frequency over the temperature range of -55 to +85°C. Since reception and transmission occur on the same channel, the stabilized receiver local oscillator is used as one of the reference frequencies in the transmitter frequency control loop. The 11.5 mc modulated oscillator controlled by a crystal discriminator AFC loop performs the side-step function, since it operates at the receiver intermediate frequency. The error signal in both control loops is derived by phase comparison of the controlled frequencies with crystal controlled references. The error signals are applied to semiconductor reactance devices in the variable frequency oscillator circuits to obtain frequency correction. In both control loops electronic hunting circuits are employed to bring the VFO within holding range of the phase comparators.

The 30 - 76 mc operating frequency range of the receiver is covered in two bands; band one 30 to 53 mc; band two 53 to 76 mc. The intermediate frequency was chosen at 11.5 mc in order that high and low side mixing of the receiver local oscillator could be used. The range of operation of the local oscillator is then restricted to 41.5 to 64.5 mc. A sampling of the local oscillator is fed to the CRS. (See figure 2 for block diagram of CRS). The fifty kc channel spacing is then achieved by three successive interpolations in the Crystal Reference System. The first interpolation occurs in the first or balanced mixer, and divides the 23 mc band coverage into one megacycle increments. Since high and low side mixing are employed in the balanced mixer, only the first 12 harmonics of a one mc crystal controlled oscillator are required. The second interpolation, which divides the one megacycle increments into 100-kc increments, is accomplished in the second mixer by a mechanically switched and synchronized crystal interpolation oscillator, employing ten crystals in 100-kc steps between 46.850 and 47.750 mc. The final interpolation is carried out in the phase comparator by the synchronized selection of one of two crystals in the Reference Oscillator at 5.60 and 5.65 mc.

In the first or balanced mixer the receiver local oscillator signal is used as the switching frequency. Since it is 25 db higher in level than the outputs of the harmonic generator, balancing of the first mixer provides nearly constant output at all receiver local oscillator frequencies. Since the mixed products of the harmonic generator present in the first mixer fed back to the receiver would lead to spurious responses, a buffer amplifier is used for isolation purposes.

Spurious receiver responses are required to be down at least 85 db. The Crystal Reference System filter complement has been designed with this in mind. The high pass filter at the input of the CRS further attenuates undesirable frequencies below 41.5 mc thus preventing receiver spurious responses. The low pass filter cuts off at 12 mc and attenuates the

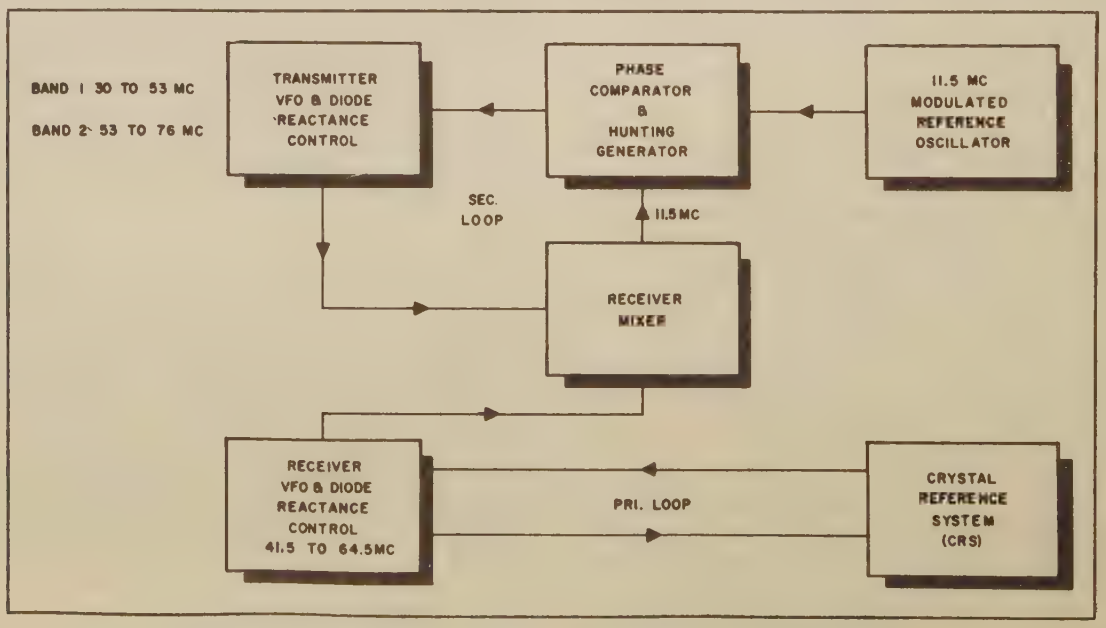
BAND 1 30 TO 53 MC
BAND 2 53 TO 76 MC
TRANSMITTER VFO & DIODE REACTANCE CONTROL
PHASE COMPARATOR & HUNTING GENERATOR
11.5 MC MODULATED REFERENCE OSCILLATOR
SEC. LOOP
11.5MC
RECEIVER MIXER
RECEIVER VFO & DIODE REACTANCE CONTROL 41.5 TO 64.5MC
PRI. LOOP
CRYSTAL REFERENCE SYSTEM (CRS)

Fig. 1 - Receiver-transmitter frequency control system.

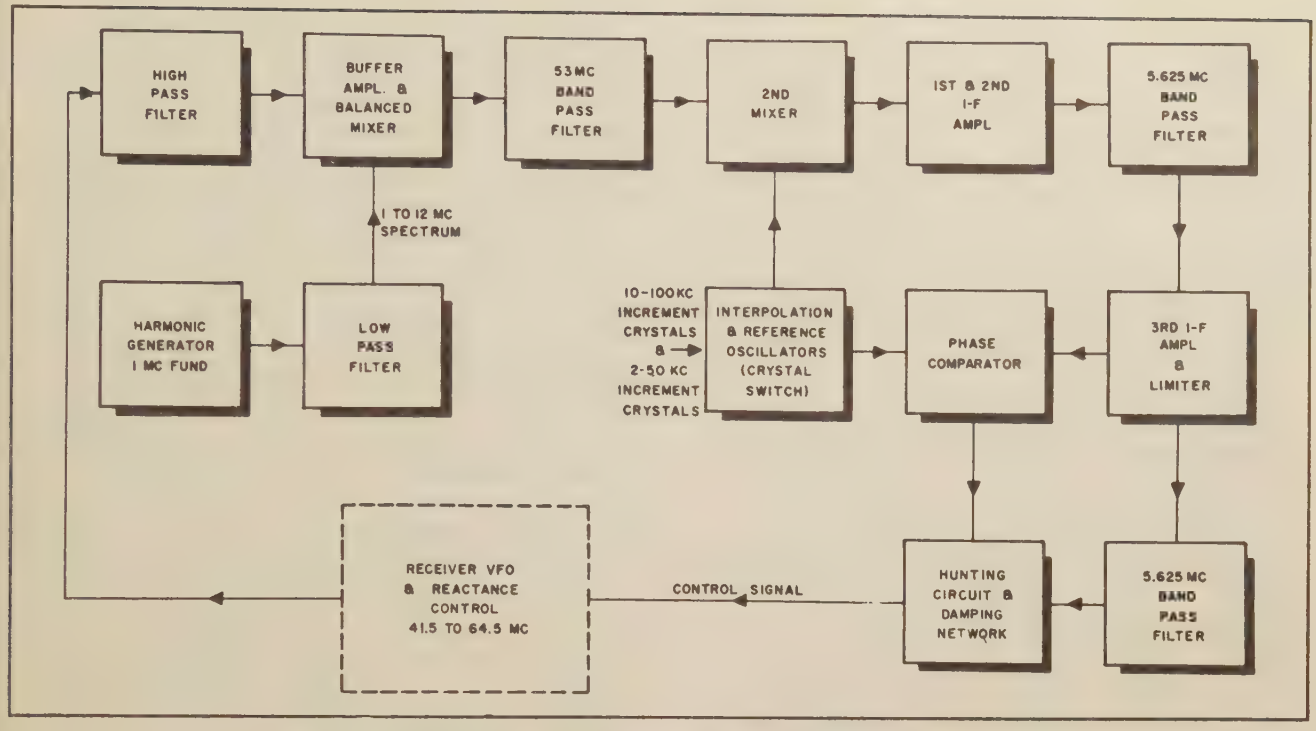
HIGH PASS FILTER
BUFFER AMPL. & BALANCED MIXER
53 MC BAND PASS FILTER
2ND MIXER
IST & 2ND I-F AMPL
5.625 MC BAND PASS FILTER
1 TO 12 MC SPECTRUM
HARMONIC GENERATOR 1 MC FUND
LOW PASS FILTER
10-100 KC INCREMENT CRYSTALS & 2-50 KC INCREMENT CRYSTALS
INTERPOLATION & REFERENCE OSCILLATORS (CRYSTAL SWITCH)
PHASE COMPARATOR
3RD I-F AMPL & LIMITER
RECEIVER VFO & REACTANCE CONTROL 41.5 TO 64.5 MC
CONTROL SIGNAL
HUNTING CIRCUIT & DAMPING NETWORK
5.625 MC BAND PASS FILTER

Fig. 2 - Crystal Reference System (CRS) primary control loop.

undesirable harmonic generator frequencies, in particular, those around the 53 mc first I-f of the CRS.

The 53 mc band pass filter attenuates the image and half I-f responses and has a bandwidth of 1750-kc. This bandwidth is required to accommodate the ±400-kc control range of the receiver local oscillator, the 900-kc range of the ten 100-kc increment crystals in the second CRS oscillator and the 50-kc displacement between the CRS reference oscillator crystals.

The 5.625 mc bandpass filters cause limiting action to occur only on the desired frequency signal in the CRS second I-f. They further prevent signals one megacycle removed on either side of the desired from disturbing the discriminator response necessary for the automatic hunting function. Due to the action of the harmonic generator, CRS first and second I-f responses can occur every one mc. The desired one megacycle interval response is pre-determined by the mechanical positioning of the receiver local oscillator within 400-kc of the required frequency. The nearest spurious then being 600-kc removed.

The interpolation and Reference Oscillators have been named somewhat arbitrarily both actually being interpolation and reference oscillators. The proper crystals in these oscillators are selected automatically by gear coupling the crystal switches to the main tuning system. The three second tuning requirements on the overall system requires a switching speed of 460 revolutions per minute for the Crystal Switch. From this it can be seen that one revolution of the switch shaft switches the control system over a 20 channel range.

Since the receiver local oscillator may be positioned as much as 400-kc from the desired frequency, an automatic hunting system is employed to bring the frequency within the holding range of the phase comparator. The hunting action is accomplished by phase splitting the output of a Travis discriminator, direct coupling one output, and capacitance coupling the other output to the reactance control circuit of the oscillator, thus achieving hunting action through instability. Hunting action automatically ceases when phase lock occurs.

The phase comparator output is applied directly to the reactance control circuit of the receiver local oscillator. Output is sufficient to override the hunting voltage and also to compensate for the frequency error of the receiver local oscillator. A damping network is incorporated to reduce control loop gain below unity at the critical frequency, to prevent loop instability. The critical frequency is defined as the error frequency at which the loop phase shift is 360°, the frequency at which instability occurs if the loop gain is greater than unity.

The maximum frequency error of the controlled oscillator is determined solely by the additive error of the various crystal oscillators. A total of 13 crystals in the CRS provides 920 crystal controlled channels. Besides the 13 crystals 12 transistors are used in the Crystal Reference System.

TRANSMIT CONTROL LOOP

One of the requirements of the receiver-transmitter is that it receive and transmit on the same frequency. In order to accomplish this, the simplest means of deriving the transmit frequency would be to use a side-step oscillator at the receiver intermediate frequency in conjunction with high and low side mixing with the receiver local oscillator. However, the 85 db attenuation requirement for spurious frequencies renders this system impractical at frequencies in the band that are near the harmonics of the 11.5 mc side-step oscillator.

Another system for deriving the transmit frequency that was investigated and breadboarded consisted of a VFO operating at the transmit frequency and sidestepped by the receiver intermediate frequency to provide an input signal to the Crystal Reference System whose output error signal controlled the VFO. The spurious responses with this system were attenuated to a greater degree than expected in the first side-step system mentioned but not enough to approach the specification requirements of 85 db. This system has another drawback in that the Crystal Reference System must be able to follow the modulation requirement of 15-kc deviation at a 15-kc audio rate the design becomes marginal as the critical frequency of the CRS is in the order of 20 kilocycles.

The present system for deriving the transmit frequency is shown in Figure 3. Here the receiver local oscillator, controlled by the CRS, is again the primary source from which the transmit channels are derived. The transmit frequency is sampled by the receiver and the receiver mixer output frequency of 11.5 mc is compared in a phase comparator circuit with the output from an 11.5 mc modulated AFC reference oscillator. The error signal from this phase comparator is applied to a semiconductor reactance control device in the transmitter VFO to maintain channel frequency. In passing, it might be mentioned that obvious advantages exist in carrying out modulation of the transmitter via the 11.5 mc reference oscillator. Namely, modulation is accomplished at a single frequency thus affording constant modulator sensitivity. Also the modulator circuit parameters are easier to control at the single lower frequency. Operationally the receive and transmit function must be accomplished on the same antenna by means of a coaxial relay. Also the transmitter frequency input level to the receiver must be controlled below a certain level to prevent generation of spurious frequencies in the control loop. With a transmitter output power requirement of 30 watts into 50 ohm at the antenna, the attenuation required of the coaxial relay to provide the proper mixer input is greater than 80 db, which is not practical. In order to overcome these difficulties the transmit frequency is fed directly into the receiver mixer from the transmitter VFO with the B/ removed from the receiver r-f amplifier. This alleviates the coaxial relay problem, since the attenuation of the receiver r-f amplifier with the B/ disabled is more than adequate. Injection at this point also minimizes effects of circuit gain variations and increases the loop critical frequency several times, since the critical frequency is a function of the phase shift of the interstage circuits.

With this frequency control system the transmitter spurious frequencies are down 85 db or greater with the exception of those in the vicinity of the i-f harmonic crossover frequencies (34.5, 46.0, 57.5 and 69.0 megacycles). Near these frequencies the attenuation is 75 db. In order to obtain the 75 db attenuation it was necessary to insert a low pass filter into the control line to attenuate the 11.5 mc signal leaking into the control from

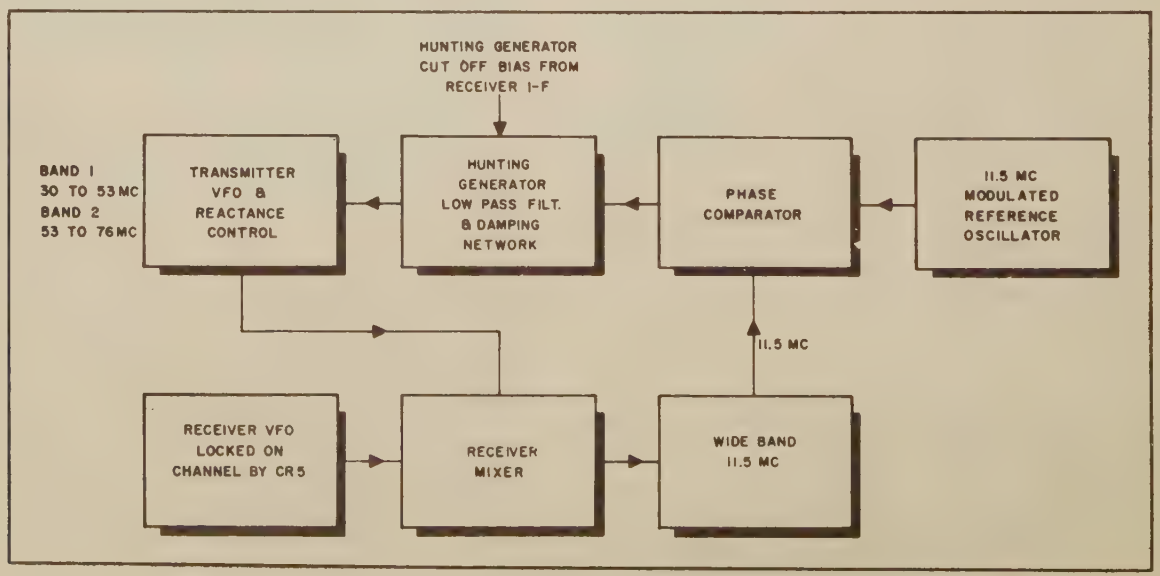
HUNTING GENERATOR CUT OFF BIAS FROM RECEIVER I-F
BAND 1 30 TO 53 MC BAND 2 53 TO 76 MC
TRANSMITTER VFO & REACTANCE CONTROL
HUNTING GENERATOR LOW PASS FILT. & DAMPING NETWORK
PHASE COMPARATOR
11.5 MC MODULATED REFERENCE OSCILLATOR
11.5 MC
RECEIVER VFO LOCKED ON CHANNEL BY CRS
RECEIVER MIXER
WIDE BAND 11.5 MC

Fig. 3 - Transmitter frequency control (secondary control loop).

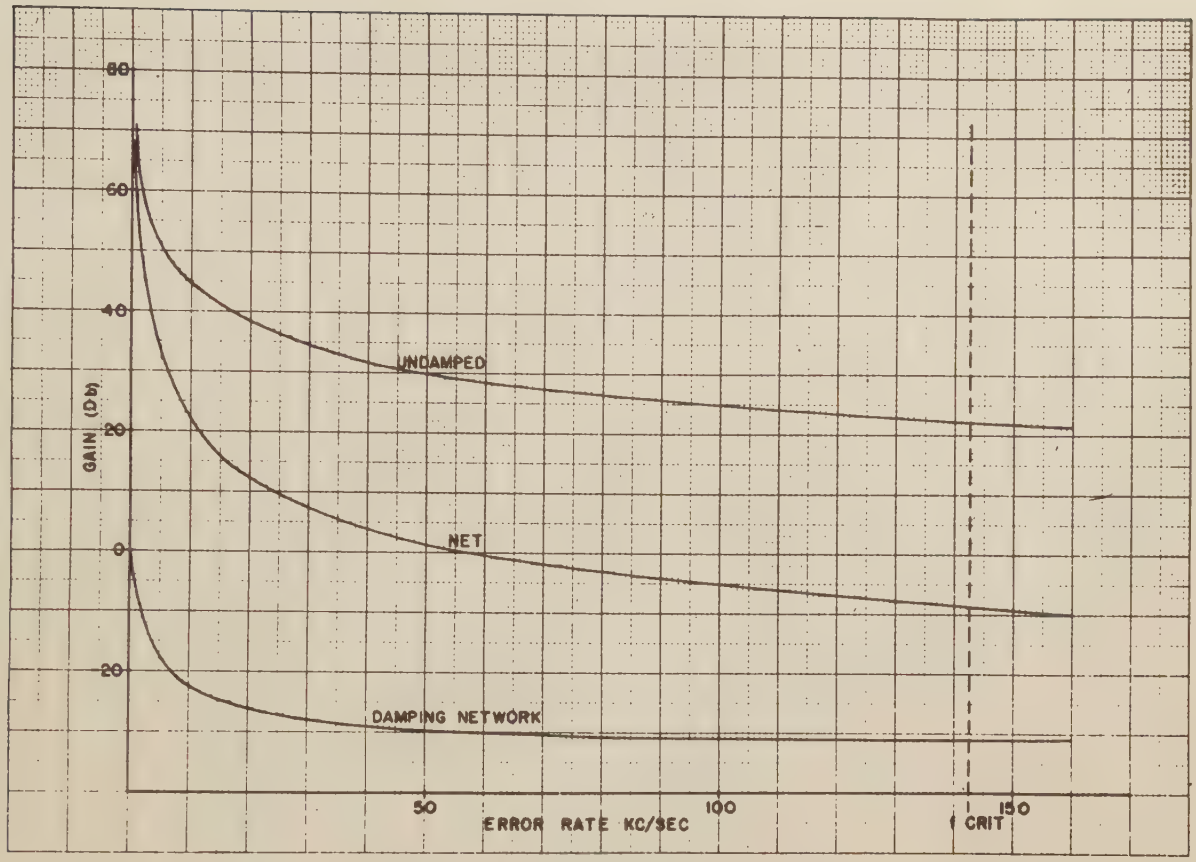

Fig. 4a - Frequency-control loop gain.

the phase comparator. The characteristics of this filter are such that it has negligible effect on the critical frequency of the system.

In this system, hunting is accomplished by means of a multivibrator circuit operating into the reactance control circuit of the VFO. The only output requirement on this multivibrator is that it be able to cause a ∠400 kc deviation of of the transmitter VFO, the maximum anticipated error from "on channel" condition. This multivibrator could be permitted to run continuously but this would cause modulation of the carrier at the hunt frequency. This has been prevented by biasing off the multivibrator with the rectified 11.5 megacycle signal derived from the receiver i-f after the crystal filter selectivity.

Figure 4-a indicates the gain characteristic of the transmitter frequency control loop versus sinusoidal error rate of modulation. The upper curve shows the undamped loop gain; the lower curve indicates the attenuation due to the damping network; the center curve depicts the net loop gain. As is customary in linear system design, according to AT-T references a gain stability margin of 10 db has been maintained in the control loop. This means simply that the loop gain at the critical frequency will be minus 10 db or less.

As mentioned previously the critical frequency is defined as the error frequency at which the total loop phase shift is 360°, the frequency at which instability occurs if the loop gain is greater than unit. This frequency occurs above 100 kc for the transmitter frequency control loop.

Figure 4-b shows the approximate phase shift of the interstage coupling circuits; the constant phase shift of 90° due to error detection by a phase comparator and error correction by a frequency modulation device; the phase shift of the damping and phase correcting network; the modulator phase shift; and the overall loop phase shift. The phase stability margin is approximately 30° as can be seen by noting the phase shift at frequencies where the loop gain is unity or greater.

Figure 4-c is a polar plot of the net gain - phase shift characteristic of the control loop.

Figure 5 indicates the maximum transmitter frequency deviation permitted during modulation by the control loop parameters. Adequate modulating capability exists, since the speech limiter in the transmitter prevents deviation in excess of 15 kc. The modulation limitations indicated by Figure 5 are based on the requirements that the control loop must simultaneously;

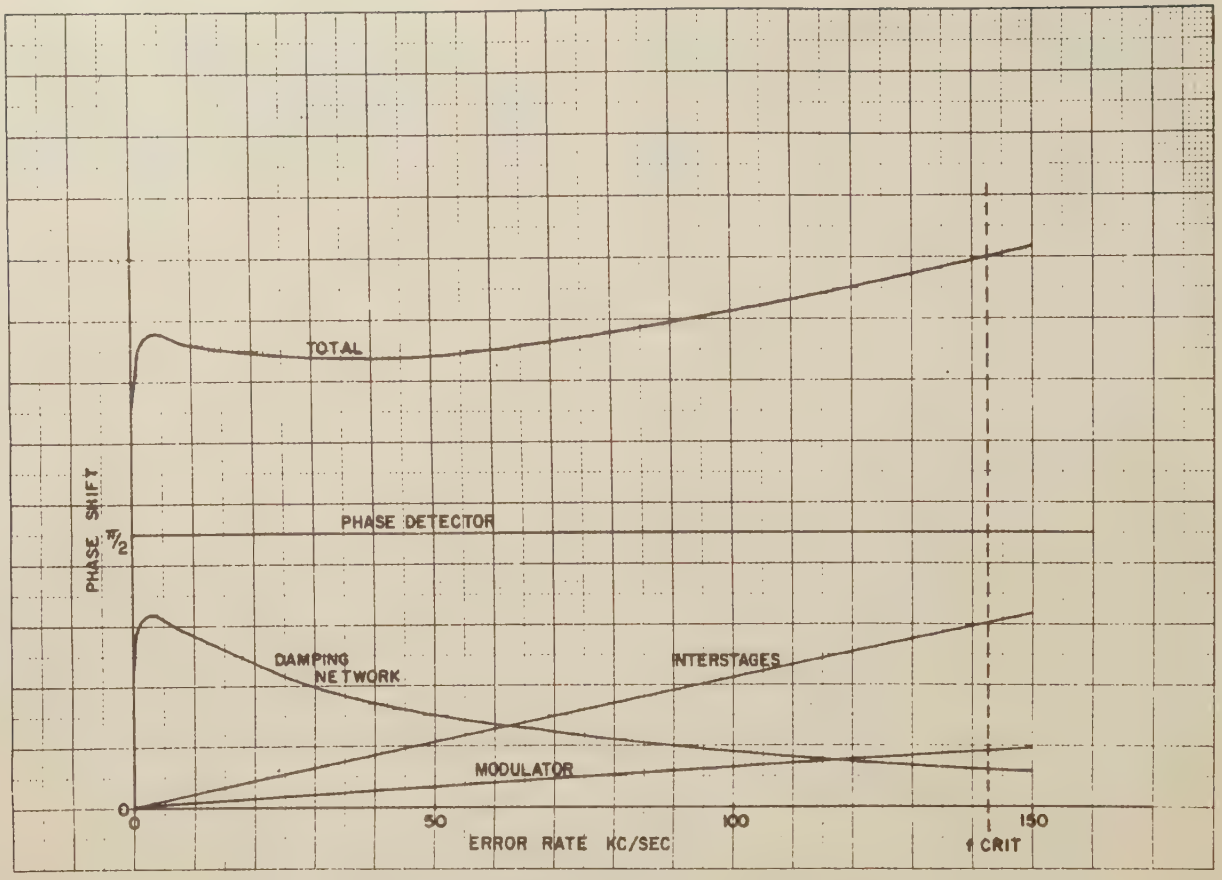

Fig. 4b - Frequency-control loop phase shift.

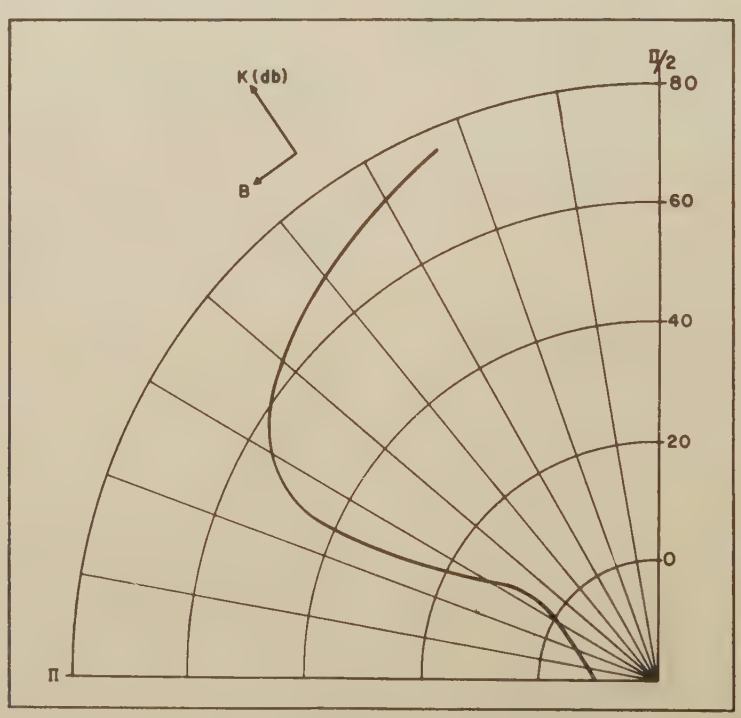

Fig. 4c - Frequency-control loop gain, phase characteristic.

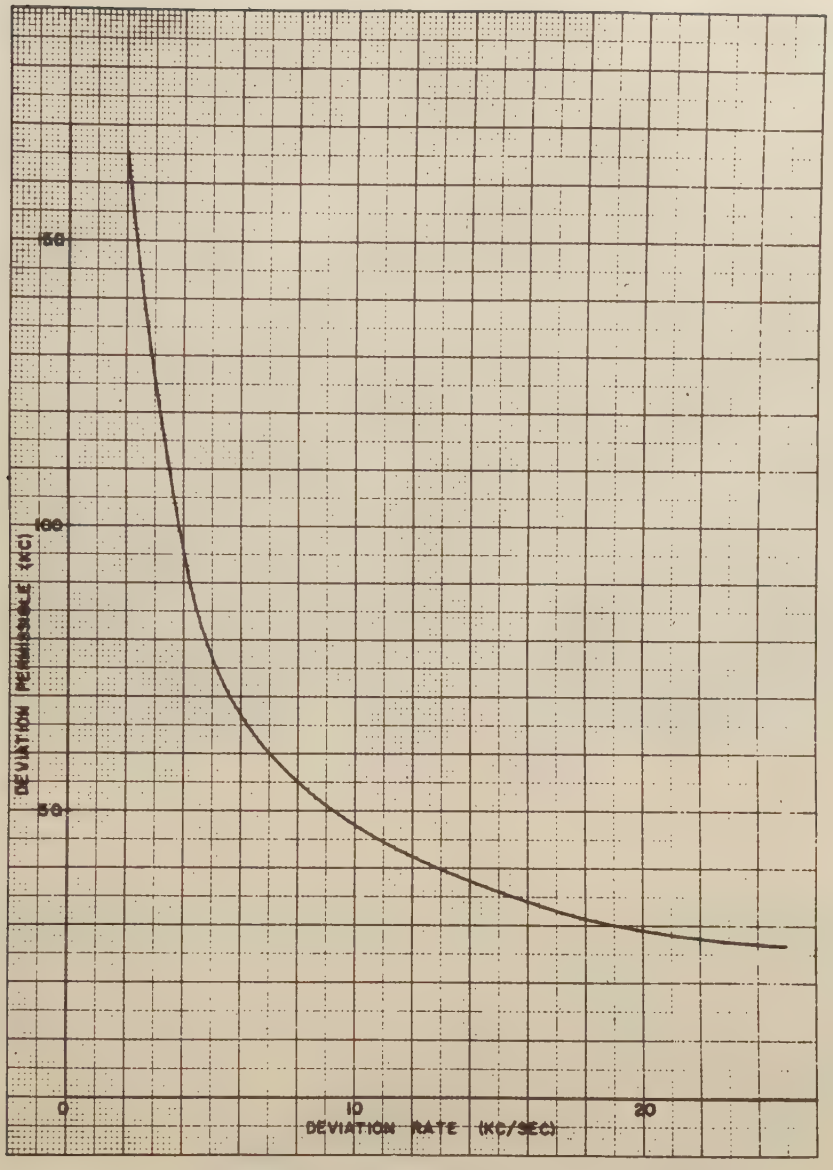

Fig. 5 - Minimum permissible modulation deviation.

1. Overcome the hunting voltage
2. Compensate for VFO frequency error
3. Achieve maximum audio modulation due to the use of a voice operated r-t relay

The audio distortion introduced by the frequency control system is so small that it is not distinguishable using standard distortion measuring equipment.

Figure 6 shows the packaging techniques employed in the Crystal Reference System. The CRS main chassis and the high speed crystal switch, which is used to select the proper interpolation and Reference Oscillator frequencies, are shown here. The breakdown into individually packaged, pre-aligned, plug-in subassemblies will facilitate field maintenance. The overall volume of the CRS, including the crystal switch, is less than 40 cubic inches. Similar packaging and miniaturization were effected for the transmit control loop.

Figure 7 shows the same units with their appropriate covers. This figure indicates the relative sizes of the units shown on the block diagram of Figure 2.

In summary, we may compare favorably the operational capabilities of this equipment, with its relative freedom from spurious responses, with that of its much bulkier predecessors. Furthermore, the equipment covers a greater frequency range in two bands than three separate individually larger units of previous equipment. At this time it should be stated that the degree of miniaturization achieved was largely due to the

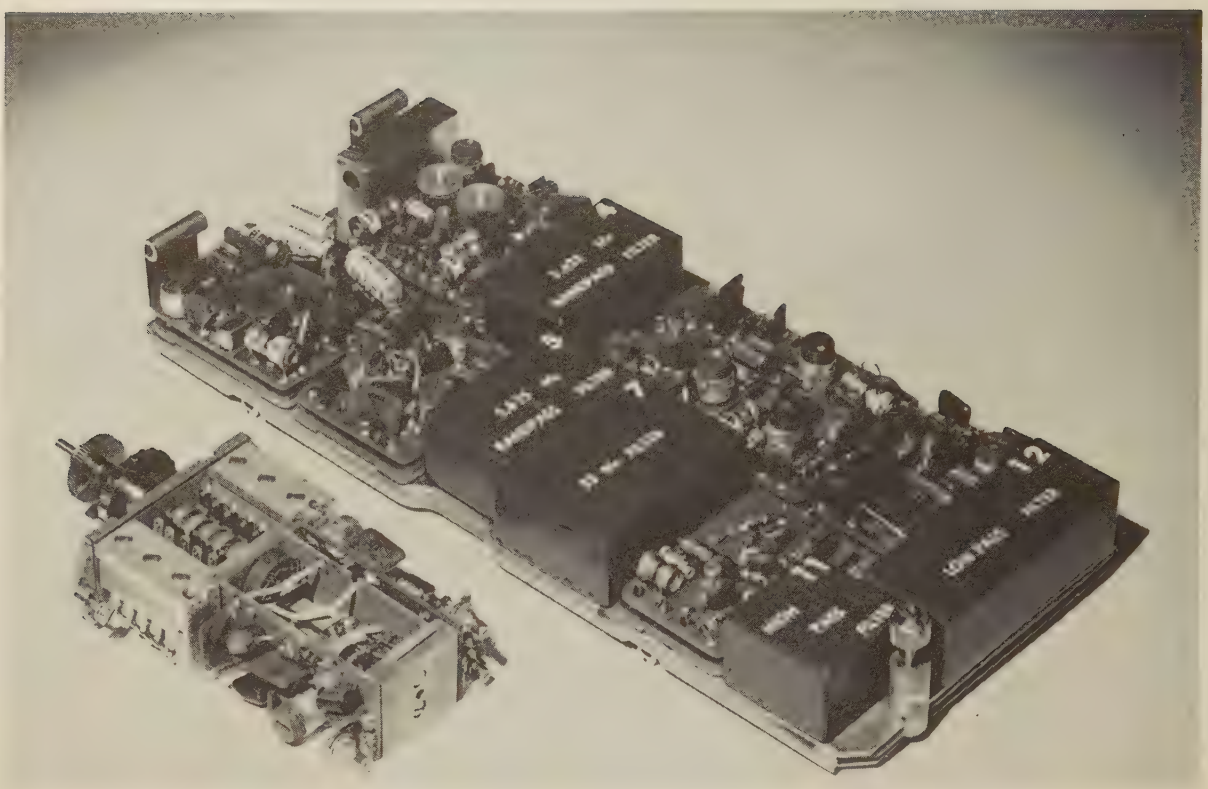

Fig. 6 - Crystal Reference System (CRS) and Crystal Switch covers removed.

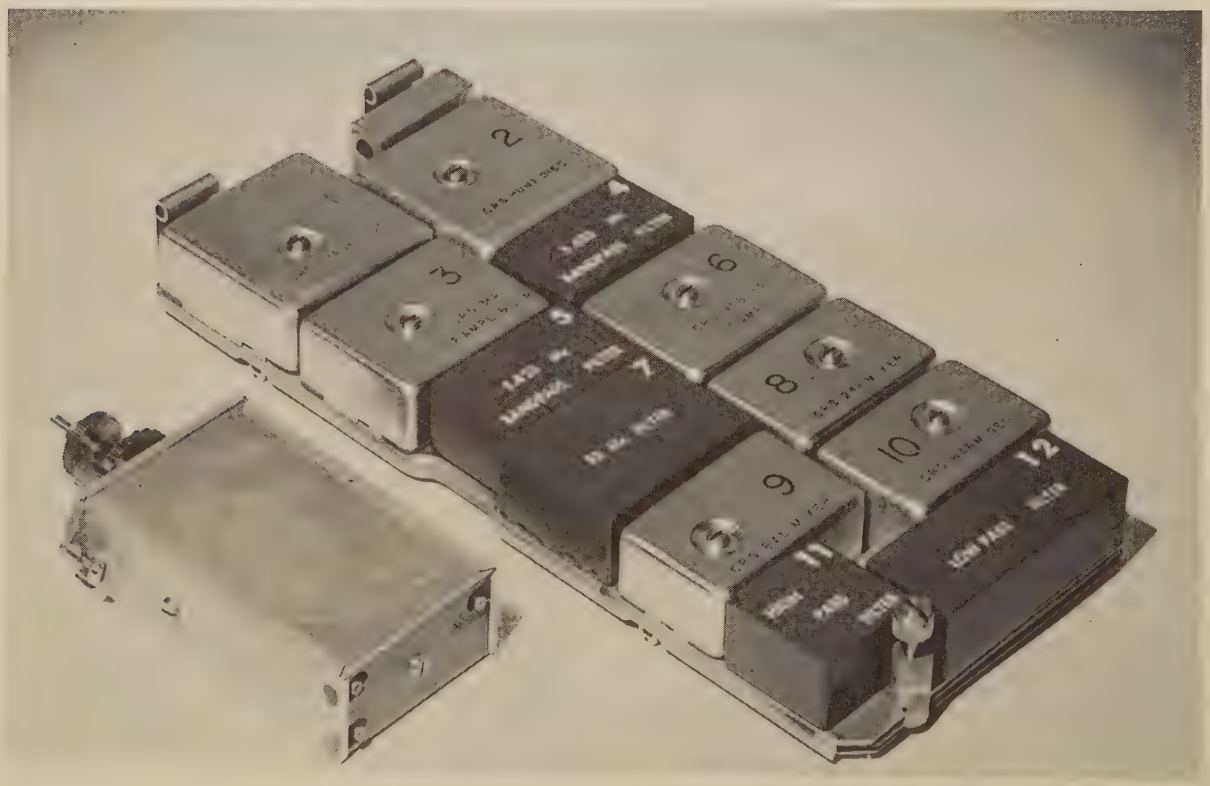

Fig. 7 - Crystal Reference System (CRS) and Crystal Switch.

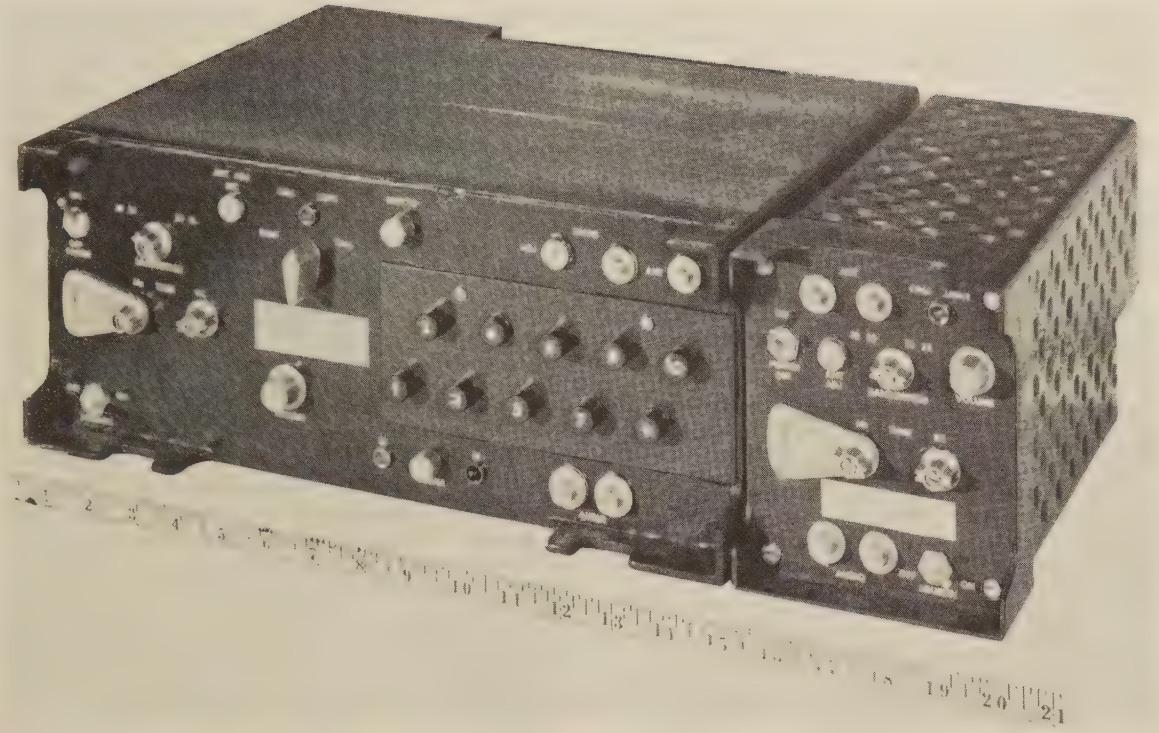

Fig. 8 - R-442 auxiliary receiver and RT-246 receiver-transmitter of the AN/VRC-12 system.

use of transistors everywhere in the equipment except in the last three power amplifiers in the transmitter. Closer frequency control and better bandpass filter techniques have resulted in double the number of channels per megacycle of specturm in comparison with previous equipment.

Extension of the techniques employed in this system may permit additional narrow channel spacings, as would be possible in Single Sideband Equipment.

Figure 8 shows a mock-up of the VRC-12 Receiver Transmitter (and auxiliary receiver) of which the CRS and the transmitter control loop described are a part.

In conclusion, the authors wish to acknowledge the assistance of the engineers of the Signal Corps Engineering Laboratories who formulated many of the concepts involved in the Crystal Reference System. We also wish to acknowledge the compentent assistance of our fellow engineers of the Communications Equipment Group of AVCO Manufacturing Corporation, Crosley Division whose efforts contributed significantly to the design of the frequency control systems employed in the VRC-12 equipment.

THE MEAT OF THE BACKBONE

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GENERAL ELECTRIC COMPANY

Summary

Several particular system design problems are discussed, in connection with the design of "backbone" type vehicular communications systems. No attempt is made to cover the overall problems of communications system design. This paper deals with some of the problems that are peculiar to "backbone" systems.

In particular, this paper discusses the variables effecting the size and seriousness of phasing areas between adjacent base stations, and methods of dealing with the problem. A method of automatic receiver selection, or "voting", is described, and overall control methods are discussed.

In spite of the title, this paper is on communications system design and not on anatomy. The backbone referred to here is a type of communications system already in rather extensive use along pipelines and power transmission lines, and on limited access highways. A backbone system is here defined as any vehicular communications system where the desired mobile coverage is over a long ribbon-like area, requiring multiple base station sites, and where these multiple base stations are all modulated, monitored and controlled over a common interconnecting communication medium, such as microwave, power-line carrier or telephone cable.

This type of vehicular communications system is becoming increasingly important for policing and maintaining limited access highways. However, it applies equally well to the inter-urban transportation field in general. Many of the design and operating problems associated with these systems are common to all mobile systems. The scope of this paper is limited to some of the problems that are peculiar to backbone systems.

First, let us consider station to mobile coverage. One of the first problems we encounter is the question of how little or how much overlap to provide between adjacent base stations. Obviously, no overlap means a discontinuity or gap in the desired coverage area. The actual amount of overlap designed into the system will be dictated by a balance between cost and desired reliability. However, the very fact that we have overlap between adjacent transmitters leads us to another problem which is neither as obvious nor as straightforward in its solution. This second problem is that of interference between adjacent transmitters operating on essentially the same frequency and modulated by essentially the same modulation - and I emphasize the word "essentially". The zone where this interference occurs I will refer to as a "phasing area". In this area, the mobile receiver is accepting two carriers of nearly equal field strength, different in phase, probably slightly different in frequency, and probably with slightly different modulation. The result is often what you might suspect - unintelligible garbage.

Let's consider some of the variables affecting the size and seriousness of the phasing area - first, the individual magnitude of the two signals at the point where they are equal. Figure 1 shows the results of tests on a high band receiver with a 20 db quieting sensitivity of .6 microvolts. The case shown on this chart is somewhat idealized, since the two signal sources were set on the same frequency but not locked in phase, and the deviation on both sources was set at ±10 kc. Curves B, C and D indicate that the introduction of hash will occur over that area where the two signals differ by no more than 4 to 5 db, as long as the individual signals (at the point where they are equal) are well above the 20 db quieting threshold of the receiver. However, curve A indicates that if the point of equal signal occurs in a relatively weak signal area, the phasing area may extend for a considerably greater distance. This is another point to consider when deciding on the amount of overlap to provide.

Figure 2 shows that, within limits, differences in carrier frequency between the two adjacent transmitters have little effect on the measured sinad ratio at the mobile receiver. On the other hand, the mobile operator will usually hear a resulting audio beat note, and this may have a serious effect on his ability to read the message transmitted. It should also be kept in mind that even if the two carriers are, for all practical purposes, on precisely the same frequency, they will still appear at the mobile antenna with random phase relationship.

Two other variables that affect the seriousness of a phasing area are the relative deviation of the two transmitters and the phase relationship of the audio fed to the two transmitters. These two effects are shown in Figure 3 and 4. If the deviation on one is set too low, or if the modulation fed to one is out of phase with respect to the audio fed to the other, the result will be a reduction in the desired audio level at the mobile speaker and a poorer sinad ratio. It should also be recognized that differences in R-F phase between the two carriers also contributes to noise in the phasing area, but since this is not a controllable variable in a practical system, there is little point in discussing its effect. It is not the purpose of this paper to go into the mathematics or

physical principles involved in these various effects. I only wish to point out what the variables are and how we can deal with them. The effects of differences in carrier frequency, deviation and audio phase are controllable to within satisfactory operating limits by system design, careful initial system alignment and meticulous maintenance procedures. In spite of everything that we do, however, there will still remain areas where mobiles will receive noisy signals with reduced intelligibility.

Well - what else can be done about these cursed phasing areas? One solution is to provide manual or automatic switching of a directive antenna system on the mobile units. Another is to place all control in the hands of a central dispatcher, with individual control of each base station transmitter. One comparatively simple thing that can be done is to make the phasing areas as small as is practicable. A significant reduction in their size and seriousness can be accomplished by applying directional antennas, with a high front-to-back ratio, as opposed to bi-directional antennas. Succeeding VHF antennas along the backbone are mounted such that the major lobe of their patterns are all oriented in the same general direction. The point of equal signal is thus displaced from mid path between the two towers. The phasing area will then occur at a point where the potential gradient of the signal from the nearest transmitter is much greater than would be the case at mid path.

Let's take a look at a specific example. Figure 5 shows the average signal strength received by a mobile unit, over a 26 mile path, between two 50 watt high band transmitters. For the sake of the example, we have assumed 100 foot towers and bi-directional antennas with 3 db gain above a dipole. The curves indicate that there would be an area three miles long at mid-path where the two signals would differ by no more than 5 db. Increasing the gain of both antennas would increase the absolute magnitude of the signal strength at mid-path, but would have little or no effect on the size of the phasing area, since the slope of the signal strength versus distance curve would remain the same.

Figure 6 is for the same path, towers and transmitters, but the antennas have been changed to directional arrays with a 31 db front-to-back ratio. The 5 db differential area is now only 2.1 miles long. Thus, we have reduced the phasing area by 30 percent. Both Figure 5 and Figure 6 are based on calculation. However, actual field tests on Indiana Turnpike and the Sunshine State Parkway showed the benefit to be actually greater than that predicted from calculations. Comparison between two essentially equivalent paths showed an apparent reduction, in the size of the hash area, of almost 50 percent.

Talk-back transmission from a mobile to base station receivers in a backbone system, presents an entirely different problem. A mobile, at any point along the system, may well be within range of two or even three base receivers. The mobile transmitter may be putting an excellent signal into one receiver, while it may be barely opening the squelch of others. In a so-called party line system, the audio from several base station receivers is fed to a common audio channel for re-transmission or control point monitoring. In order to avoid super-imposing noisy signals on the desired signal, some means of automatic receiver selection is required. Preferably, the receiver selected, to the exclusion of the rest, should be the one receiving the best signal. We choose to call such a control system, "Receiver Voting". At this point I could just let the subject drop, but I thought some of you might be interested in a description of a simple, straight forward system for accomplishing the desired end result. It goes like this:

Upon receipt of a signal from a mobile transmitter by two or more base station receivers, automatic selection is made by a combination of a fixed priority system and a variable relative time delay dependent upon the received signal strength. Sounds impressive, doesn't it? Actually, it's fairly simple.

Each of the station receivers, in a given segment of this communications system, is assigned a fixed priority. In general, this priority would be assigned in order of the reliability of the intervening circuits. That is, the receiver that is connected to the control point via the circuit least susceptible to probable failure, or the circuit with the best signal-to-noise ratio, would be assigned top priority, all other factors being equal. When a mobile signal is received at two or more fixed station receivers, each receiver actuated initiates an individual control function to the control point. When the received signal strength is essentially equal at two or more station sites, the receiver assigned the highest priority takes precedence, and all other receivers are locked out.

At the same time, a device is included with each base receiver which delays the initiation of the voting control function. This time delay is controlled by the first limiter current in the receiver in such a way that it is inversely proportional to the received signal strength. Thus, a receiver at a point of significantly superior signal strength can be made to over-ride the priority arrangement on a first-come-first-served basis.

Figure 7 shows the circuit of the time delay device or Voting Delay Panel. During standby, the R-C network in the grid of V2 is charged to a potential determined by the setting of R2. When a mobile signal is received, carrier operated relay contacts close the circuit between P3 and P4. The grid voltage on V2 is the series combination of the drop across V1 and the exponentially decaying voltage across C3. The conduction of V1, and thus the time between operation of C.O.R. contacts and operation of K1, is controlled by a portion of the receiver

first limiter grid voltage fed to the grid of V1 via P2.

Figure 8 shows the necessary circuitry to provide the combined priority and time delay "voting" at the control point for a four receiver system. The contacts labeled TDS 1, 2, 3 and 4 are actuated by the incoming receiver voting control functions. Relays K1, K2, K3 and K4 provide the fixed priority operation. Relays K5, K6, K7 and K8 function according to the relative time of operation of TDS 1, 2, 3 and 4.

Of course, this is not the only method of receiver voting possible, but it has the factor of simplicity in its favor.

Still another key problem in the design of backbone systems is the audio and control circuitry in the backbone itself. Basically we have a choice of operating and monitoring all stations, in a given segment of the system, simultaneously on a party-line basis, or providing means for selecting individual stations at the discretion of a Master Control operator. The straight party-line system has the advantage of simplicity of operation. All mobiles and fixed points monitor both sides of all conversations on the system, and the principal dispatcher, or Master Control, operates the entire system as though it were a single base station. On the other hand, individual control provides an added degree of flexibility. I favor a combination of the two. For the majority of traffic, the system should operate as a party-line. This permits the most rapid and efficient utilization of the channel, and avoids the necessity of relaying messages by the dispatcher. However, individual control of all base stations (on separate backbone channels) should be available to the Master Control point. The dispatcher will find it desirable, at times, to isolate a portion of the system for strictly local radio traffic, without tying up the entire system. This facility also permits him to cut out a station receiving interference or causing faulty operation of the system.

Above all, there is one key point I would like to make before concluding. It is true that backbone systems require certain special devices and techniques to provide adequate overall performance, but there is a terrible temptation to continue adding more and more frills and furbelows until the system is a maintenance man's nightmare. Simplicity should be the key-note. Straightforward design and simplicity of operating and maintenance procedures may well do more for reliability than all the standby equipment in the industry.

The backbone requires sufficient meat around it to keep the vertebrae from rattling, but excess meat reduces agility.

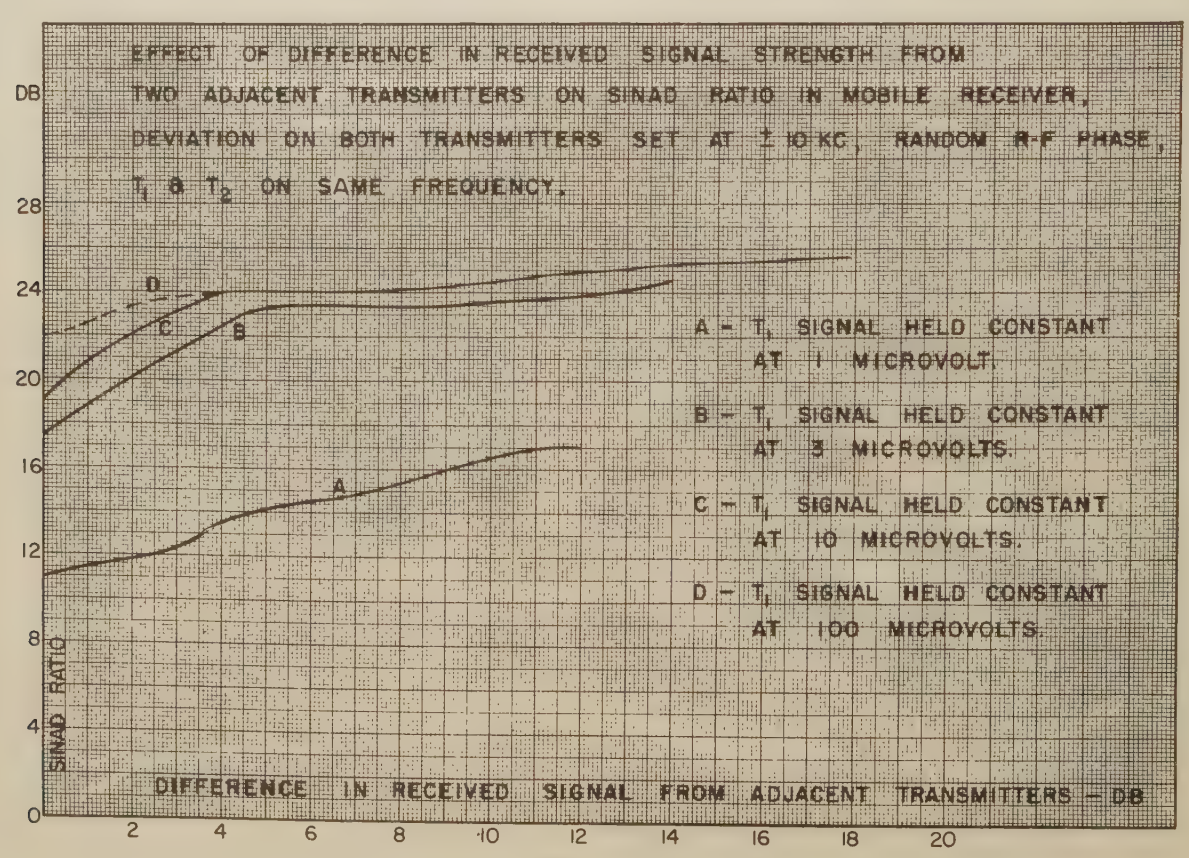

Fig. 1

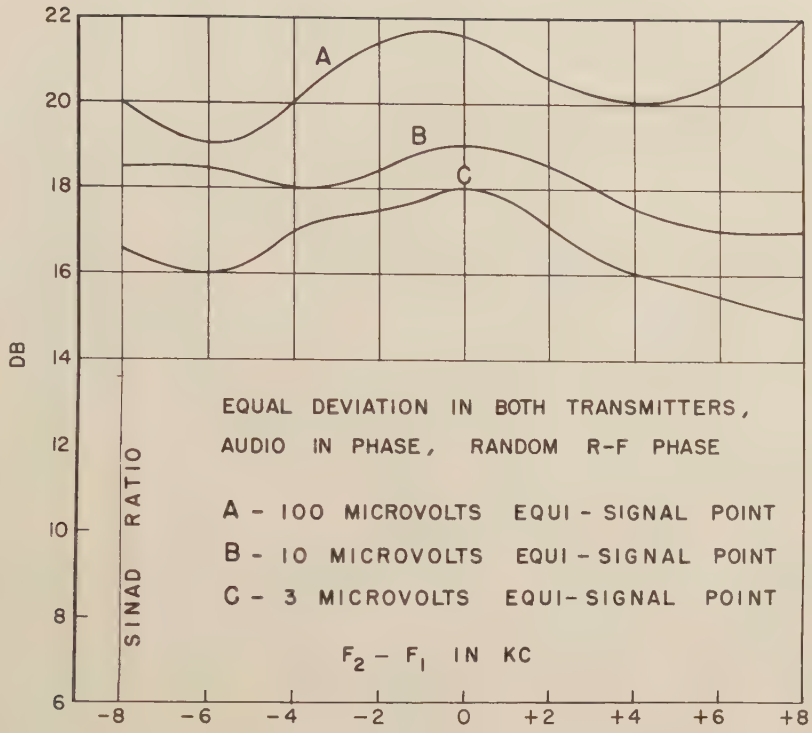

Fig. 2 - Effect of difference in carrier frequency between two adjacent transmitters on sinad ratio in mobile receiver at point of equal signal.

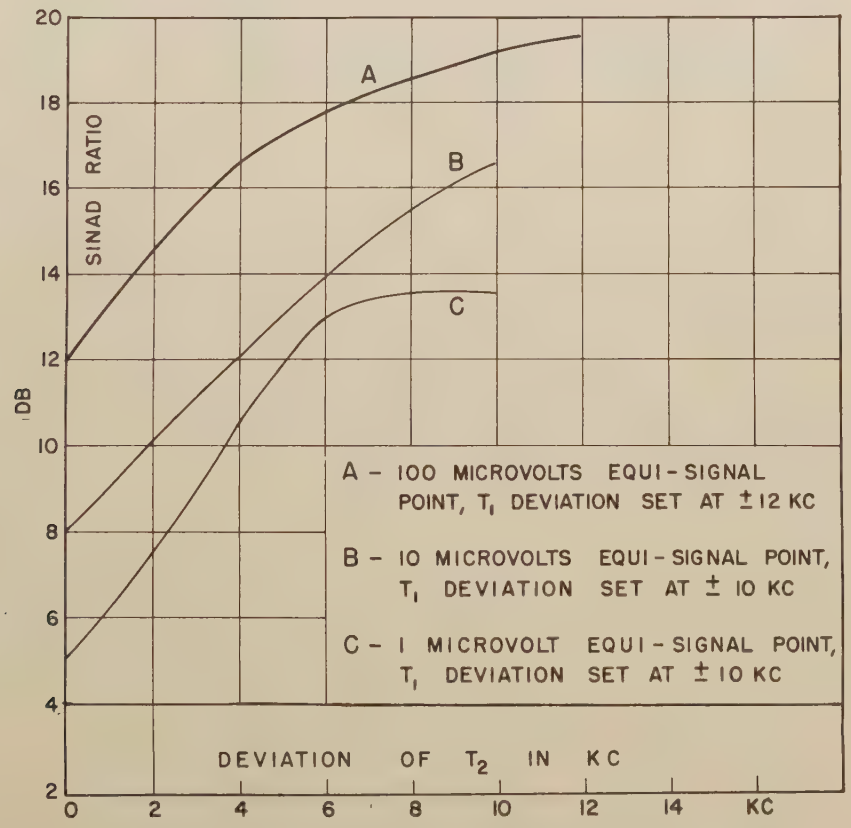

Fig. 3 - Effect of difference in deviation between two adjacent transmitters on sinad ratio in mobile receiver, equal received signal strength from both transmitters on same frequency, deviation of T_1 held constant.

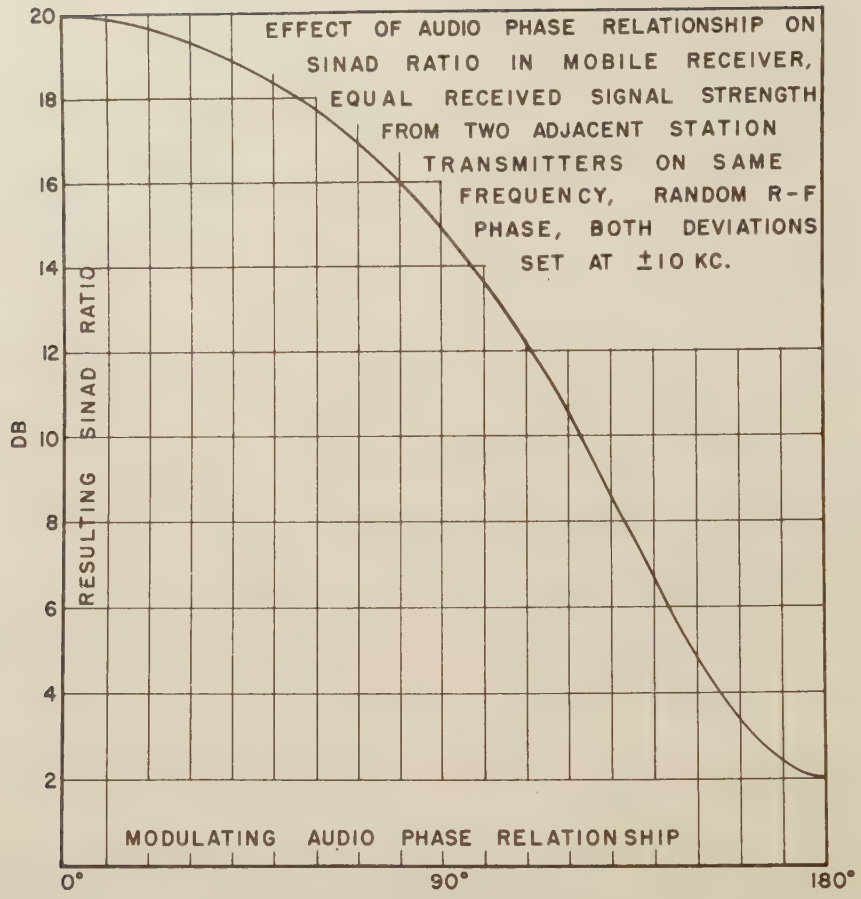

Fig. 4

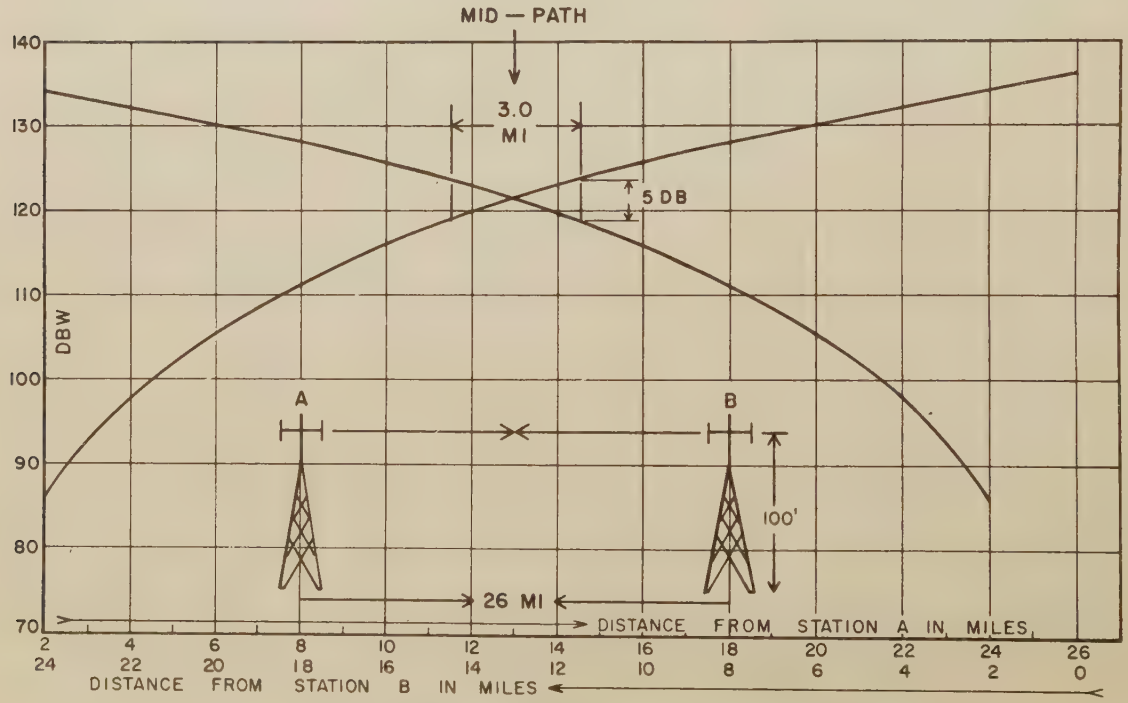

Fig. 5 - Predicted phasing area size, bidirectional antennas.

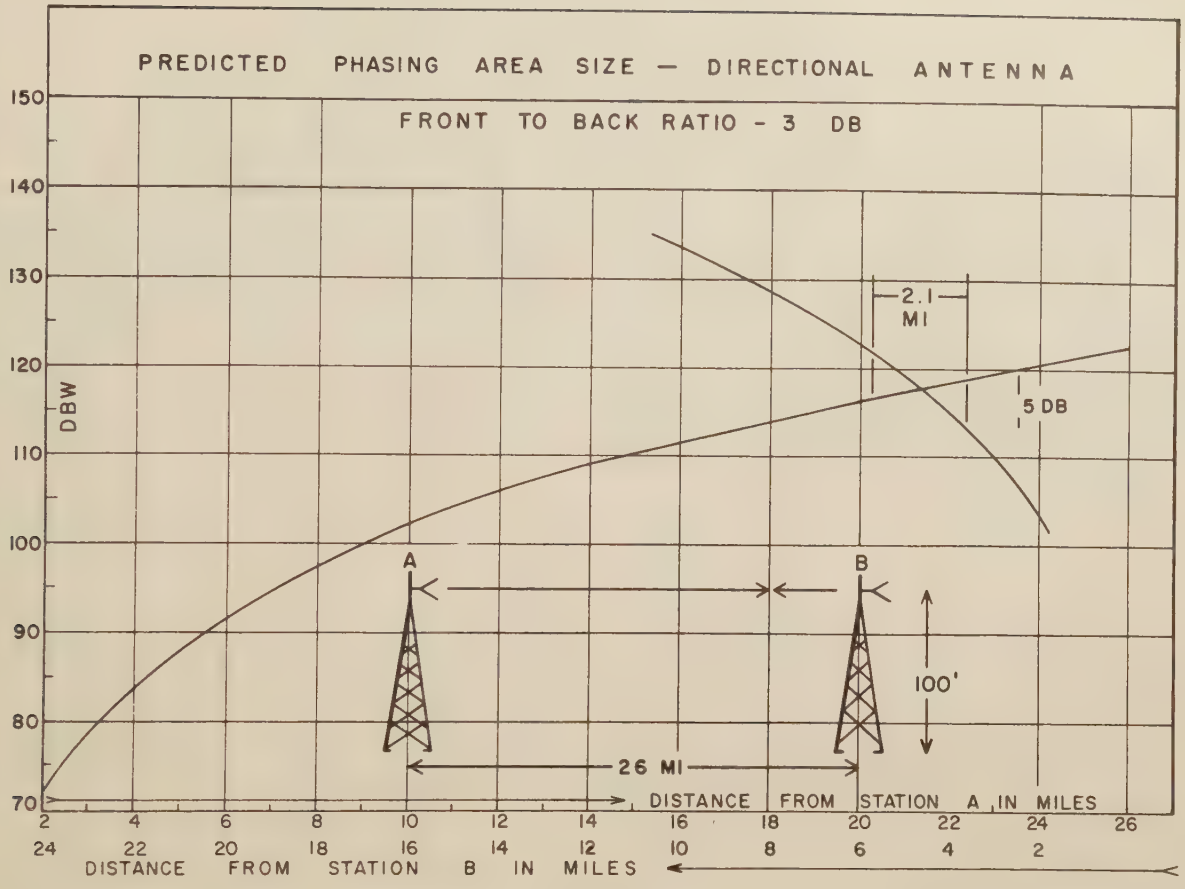

Fig. 6

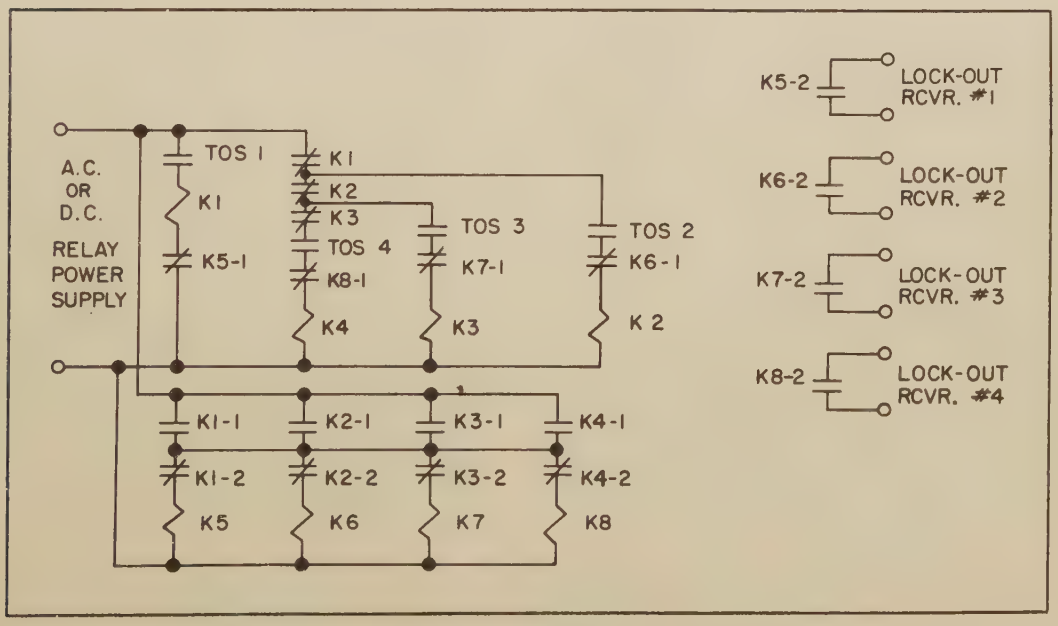

Fig. 7 - Receiving "voting" lock-out circuit.

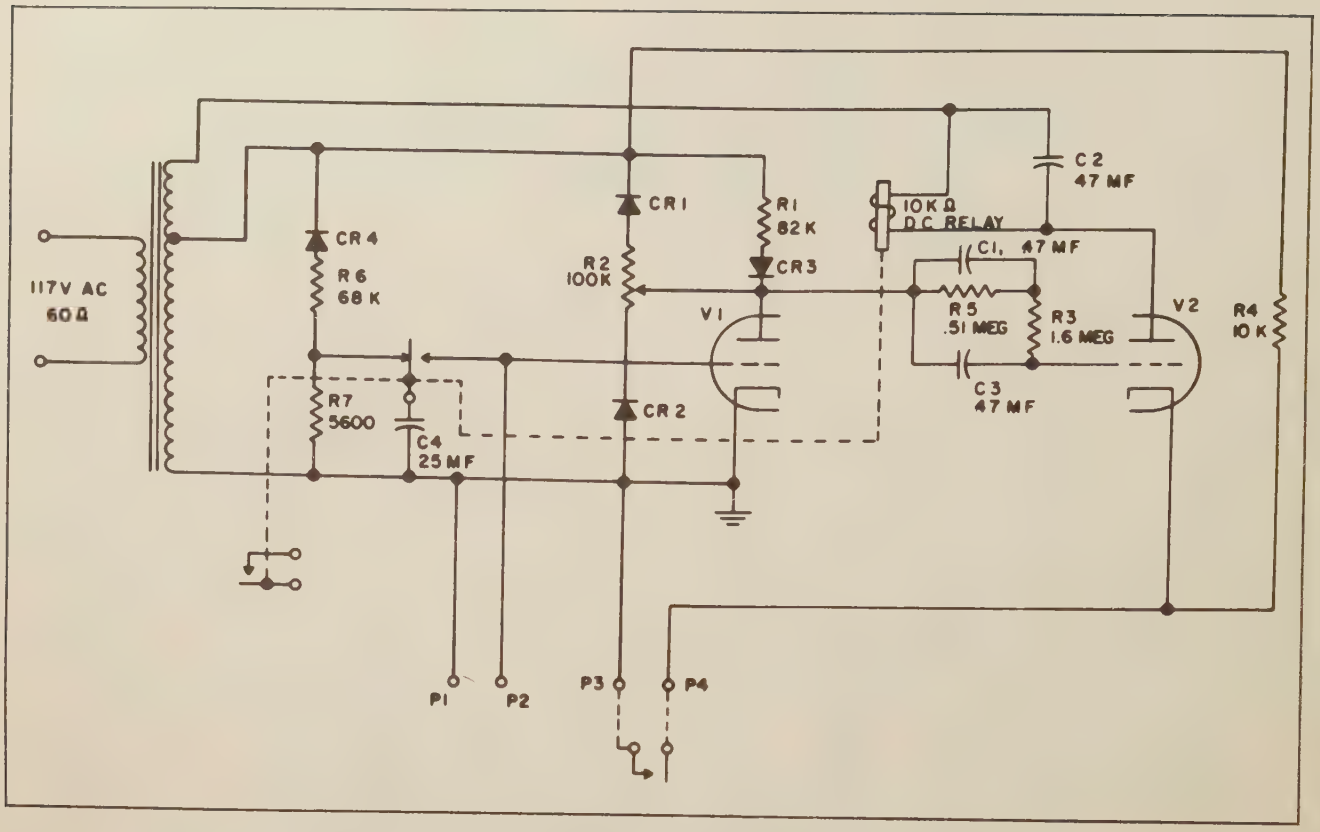

Fig. 8 - Elementary diagram receiver voting delay unit.

DIAL OPERATED MOBILE RADIOTELEPHONE SYSTEMS

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Rural Electrification Administration
United States Department of Agriculture

Summary

This paper describes radiotelephone equipment that makes it possible for small telephone companies with dial exchanges to offer 24-hour mobile radiotelephone service to its subscribers. Similar radiotelephone service can be given to subscribers in remote locations who could not otherwise be served by conventional wire line facilities. The equipment may also be used by a telephone company for its own use incident to construction and maintenance of outside plant. The equipment was developed to Rural Electrification Administration specifications by the Automatic Electric Company and Motorola, Inc., under separate contracts and has been successfully field-tested.

The telephone exchanges of most REA borrowers are of the automatic dial type and very few borrowers have toll centers with operators available to handle mobile calls. Lacking switchboard operators, these small companies can offer mobile radiotelephone service to their subscribers only on a limited dispatch or an automatic dial-operat operated basis.

Dispatch Service

In the dispatch type of service, office employees handle calls to and from mobile vehicles during regular office hours. This type of service is of limited value to the general public but it is valuable to a telephone company for use in the maintenance and operation of its system. Under present FCC rules and regulations, frequencies are not available solely for a company's own use in the maintenance, construction, and operation of its facilities. However, channels allocated for common carrier mobile service may be used by a telephone company for maintenance if a public offering is made to provide mobile service to others in the area who desire it. A dispatch type of service will meet this requirement.

In offering dispatch type service it is desirable for the base station to be arranged so that the received signal can be simultaneously retransmitted when desired, i.e., arranged for mobile relay operation. This would permit mobile-to-mobile operation which is of particular value during storms or at night when no one is at the office to repeat messages orally between mobile units. Two mobile units can communicate with each other as long as both are within radio range of the same base station.

Basic Operation of Dial Radiotelephones

For a telephone company with dial exchanges but no switchboard operators, dial operated radio equipment is the only economical method of providing 24-hour radiotelephone service to mobile and rural subscribers. Dial operated radiotelephones may be used to provide subscriber service to vehicles of physicians, veterinarians, taxis, business firms, etc. They may be used to provide radiotelephone service to residences, ranches and resorts in remote locations where construction of wire line facilities is impractical and to establish temporary service in emergencies, either to a new subscriber or to one whose service has been interrupted. In addition, they can be installed in a telephone company's own vehicles for use in the construction and maintenance of its system. Fig. 1 is a schematic of a two-way radiotelephone dialing system connected to a dial telephone exchange.

Development

For several years REA tried to interest radio manufacturers in the design and manufacture of mobile dial radio equipment. At first the manufacturers could not be convinced that the market was large enough. However, in May 1956, REA wrote specifications and telephone and radio manufacturers were invited to submit bids for furnishing two mobile radiotelephone units, one rural subscriber station, and one base station with the associated antennas. Bids from the Automatic Electric Company and Motorola, Inc., were accepted.

The specifications were written so that commercially available base and mobile radio equipment would be used as far as possible in the dial operated radio equipment. In other words, the equipment to be developed was to be primarily appliqué equipment that would go between standard radio equipment and the telephone exchange equipment.

Design Common to Both Makes of Equipment

The dial radio equipment designed by both Automatic Electric and Motorola is for single channel, two-frequency operation in the 152-162 mc band, with push-to-talk operation in the mobile units. Presently there are six pairs of frequencies available for mobile use in this band. An additional four pairs may be used for rural radio service provided there is no harmful interference to mobile service in the area. Two frequencies with a 5 mc separation are used for each channel, one for transmitting and one for receiving.

The base station transmitter of both makes is on the air for the duration of the call and repeats the conversation received, whether from the exchange or from a radiotelephone subscriber. From the radio standpoint, the base station is similar to a conventional mobile relay station. It permits mobile-to-mobile calls and, when desir-

ed, allows monitoring of both sides of a conversation. Also, when the base station transmitter is on the air, busy lights are lit in all mobile units.

The power output of the base station and one mobile unit is 50 watts. The second mobile unit and the rural subscriber station has a power output of 25 watts. The dialing and supervisory signals are received as conventional signals by the telephone exchange switching equipment.

In May 1957, the Motorola equipment was installed in the system of the Central Virginia Telephone Corporation, Amherst, Virginia. The Automatic Electric equipment was installed in July 1957 in the Branford Exchange of the North Florida Telephone Company, Live Oak, Florida.

Automatic Electric Equipment

With the Automatic Electric equipment a standard rotating telephone dial is used on the control head of the subscriber sets. These units are quite similar to conventional cradle telephones except for a locking device used to prevent the handset in mobile units from bouncing out of the cradle. Removal of the handset turns the transmitter on for about 2 seconds; this, in turn, puts the base station on the air, makes the necessary connections with the telephone exchange, and returns dial tone to the mobile unit.

Operation

A 2000-cycle gate tone is transmitted when the dial is moved off normal. This tone operates a slow-operate relay which removes a short from across a line pulse relay and remains operated until the end of the pulsed digit. A 1500-cycle tone is pulsed as the dial returns to normal. When the pulsed tone is received by the base station, it is converted to conventional d-c pulses and forwarded to the telephone exchange switching equipment to select the called subscriber. Both the gate tone and the pulse tone must be received before any actual dialing can occur at the telephone exchange.

Revertive Calls

The Automatic Electric Company has a unique method of making revertive calls, independent of any revertive switching equipment in the telephone exchange. When a mobile subscriber wants to make a revertive call, pressing a pushbutton on the side of the control head places the mobile unit on the air with a 2500-cycle tone. Reception of this tone at the base station disconnects the telephone line, busies out the radio circuit to all other subscribers, and readies the "reverting call translator." The mobile subscriber then dials two digits to select the desired party on his channel. The first digit selects the ring code and the second transmits two tones to select one of every multiple of 10 mobile units. In other words, on revertive calls there is full selective calling for 10 subscribers and semiselective calling for 20 subscribers. Also, if desired, one can use the standard revertive call technique used in the exchange.

Motorola, Inc., Equipment

There is a considerable difference between the operation of the two systems when a call is made from a mobile unit. Motorola uses primarily electronic circuits; Automatic Electric uses conventional telephone relays. The Motorola equipment, using a push-button control head, transmits three tones for each digit. There are 11 buttons, one for each digit plus a revertive call button. "Two-out-of-four" tones in the audio band 1900-2700 cps are transmitted in a sequential combination to represent a digit; a fifth tone, i.e., the third one transmitted, is used as an interdigital tone. The tones are generated from a single transistor in the control head.

Operation

When the mobile handset is removed, the push-to-talk button is pressed momentarily. This transmits rf carrier to the base station which turns on the base station transmitter and makes the necessary connections with the exchange to return dial tone. Then, when a button is pressed for a given digit, the three tones are transmitted to the base station. There they are translated into the required number of conventional dial pulses and forwarded to the exchange switching equipment. The tones are of long enough duration (200 to 300 milliseconds) so that if dialing is done in a weak-signal area while a vehicle is in motion, complete loss of a tone from flutter of the signal due to reflection from trees or other objects will be less likely to occur. However, if a tone is not registered, no digit will be passed to the exchange. There will be a partially dialed number rather than a wrong number.

Revertive Calls

From a mobile unit, a call to another party on the same channel, i.e., a revertive call, is made in the same manner as a party-to-party call on a regular party line. It uses standard revertive call equipment in the exchange. After the revertive call number of the desired mobile unit is "dialed", pressing a revertive call button simulates the "hang-up" signal as required for the revertive call equipment in the exchange. In the Amherst installation the bell rings first in one mobile unit and then in the other until the called party answers.

Similarity of Operation of Mobile and Wire Line Telephones

The initial equipment of both Automatic Electric and Motorola is designed to handle 10 subscribers on a full selective calling multiparty basis from a line circuit in the exchange. This subscriber service is very similar to that on any multiparty line. The base station equipment of both companies can be modified to handle 20 or

more subscribers by using an additional line circuit of the exchange for each additional 10 parties.

Both makes permit a telephone wire-line subscriber to dial any mobile subscriber within range of the base station. Likewise, except for toll calls, a mobile subscriber can dial any wire line subscriber without the aid of an operator. Any type of call, such as revertive, direct distance dialing, etc., that can be made by wire line subscribers can also be made by mobile telephone subscribers.

In either make, when a call is made from a wire line subscriber to a mobile unit, the base station detects the side of line and ring code of the mobile unit being called, sends out two tones which ring a bell or buzzer in the mobile unit being called, and lights the busy light in all other mobile units. In case of emergency when a circuit is in use, provision is made so a second mobile unit can break in and request the use of the circuit.

Fail Safe Operation

Both systems are "fail safe" which means that if the station is not taken off the air by disconnect signals from either the telephone exchange or mobile unit after completion of a call, a timer in the base station will take the base station off the air. For example, if a vehicle initiating a call travels beyond radio range of the base station and disconnect tones (which are transmitted by both makes when the handset is replaced in its cradle) are not received, the timer will take the station off the air after a given interval. This interval can be set for any time up to 5 minutes. The timers in both installations are set for less than 2 1/2 minutes.

Future Development

In addition to Automatic Electric and Motorola equipment, dial radiotelephone equipment soon will be available from the Allen B. DuMont Laboratories and the General Electric Company. When these companies have equipment available, REA will field test it in borrowers' telephone systems.

Compatibility with Bell Systems

Subscribers using dial-operated mobile units may place calls when in areas of other systems that use mobile operators, such as Bell Companies. The mobile operator will answer as soon as a mobile unit transmits its carrier, assuming operation on the same frequency. However, a mobile unit cannot be called unless the operator has a code-sending device compatible with the receiving selector in the mobile unit. It is possible to install the necessary selector equipment in dial-operated mobile units so they can be called by a Bell mobile operator.

However, we believe that most mobile subscribers using dial radiotelephones would be satisfied simply with being able to place calls when within radio range of Bell mobile radio systems. If additional selector equipment were installed in these dial mobile units so that a Bell operator could call them, the rates for units so equipped would have to be considerably higher.

FCC Requirements

Waivers for Automatic Operation

Part 21 of the FCC rules requires that an operating log be kept on calls by an operator at a control point. When an application is filed for a dial system, waiver of this rule should be requested.

Base Station Identification

FCC rules also require the base station of each system to be identified by voice or tone at the end of each transmission. This is done in both systems by automatically transmitting the station call sign in Morse Code. Notches are cut in the periphery of a disk; a short notch for a dot and a long notch for a dash. As the disk rotates, a pawl falls into the notches, closing a contact which causes an audio tone to modulate the transmitter. When the disconnect signal is received from a mobile unit, wire line station, or timer, a motor starts the disk rotating. The station is held on the air until the disk makes one revolution (4 to 5 seconds), so that the call sign is transmitted once at 25 or less words per minute.

Mobile and Rural Subscriber Identification

FCC rules also require each mobile and rural subscriber station, as well as the base station, to identify itself individually at the end of each transmission. Since all mobile and rural radio transmissions are retransmitted by the base station and thus are identified with the associated base station, it is desirable to request a waiver from the FCC to eliminate the requirement that each mobile and rural subscriber identify itself individually.

Temporary Service

It is suggested that when an applicant files for a construction permit for base and mobile units, an application be filed also for a few stations to be operated at temporary fixed locations. Such a blanket license would authorize installation of a station as soon as a request is received for temporary or emergency radiotelephone service at a fixed location. However, as soon as it is known that a station so installed is to remain at that location for more than 6 months, FCC Forms 401 and 403 should be filed simultaneously for the fixed location.

Field Experience

Field experience to date indicates that both makes of equipment were well designed. The number of "bugs" which one expects to show up in new equipment were few and of minor nature. The

equipment has been used extensively by the three subscribers in each installation.

The mobile radiotelephones were installed in telephone company vehicles at Amherst and at Branford. The fixed rural subscriber telephones were also installed in the residences of employees. A recording meter installed at the fixed station location at Raphine, Va., to measure signal strength of the Amherst base station also gives the duty cycle of the base station.

Traffic Data

The record indicated that approximately 370 calls were made over a three-week period (September 21 to October 12) or an average of 17 calls per day for the three subscriber radiotelephones. The average length of each conversation was about 1 1/2 minutes. The longest call was 25 minutes.

The telephone company will install 7 additional radiotelephones in subscriber vehicles within the next few months. It will be of interest to note the characteristics of those calls compared with calls made by the telephone company employees.

Conclusion

The REA contracts for the development of dial mobile radiotelephone equipment and the successful operation of the Automatic Electric and Motorola equipment during the past 6 months of field testing are major steps toward making it possible for small telephone companies to provide mobile and rural radiotelephone service to the public within the areas now served by wire lines.

We are pleased with the cooperation and interest which the Central Virginia Telephone Corporation and the North Florida Telephone Company have shown in allowing these tests to be made on their systems. Also, we appreciate the cooperation of the FCC in granting the necessary rule waivers to permit automatic operation. The interest generated and the publicity given these installations have spurred other companies to develop dial operated mobile equipment.

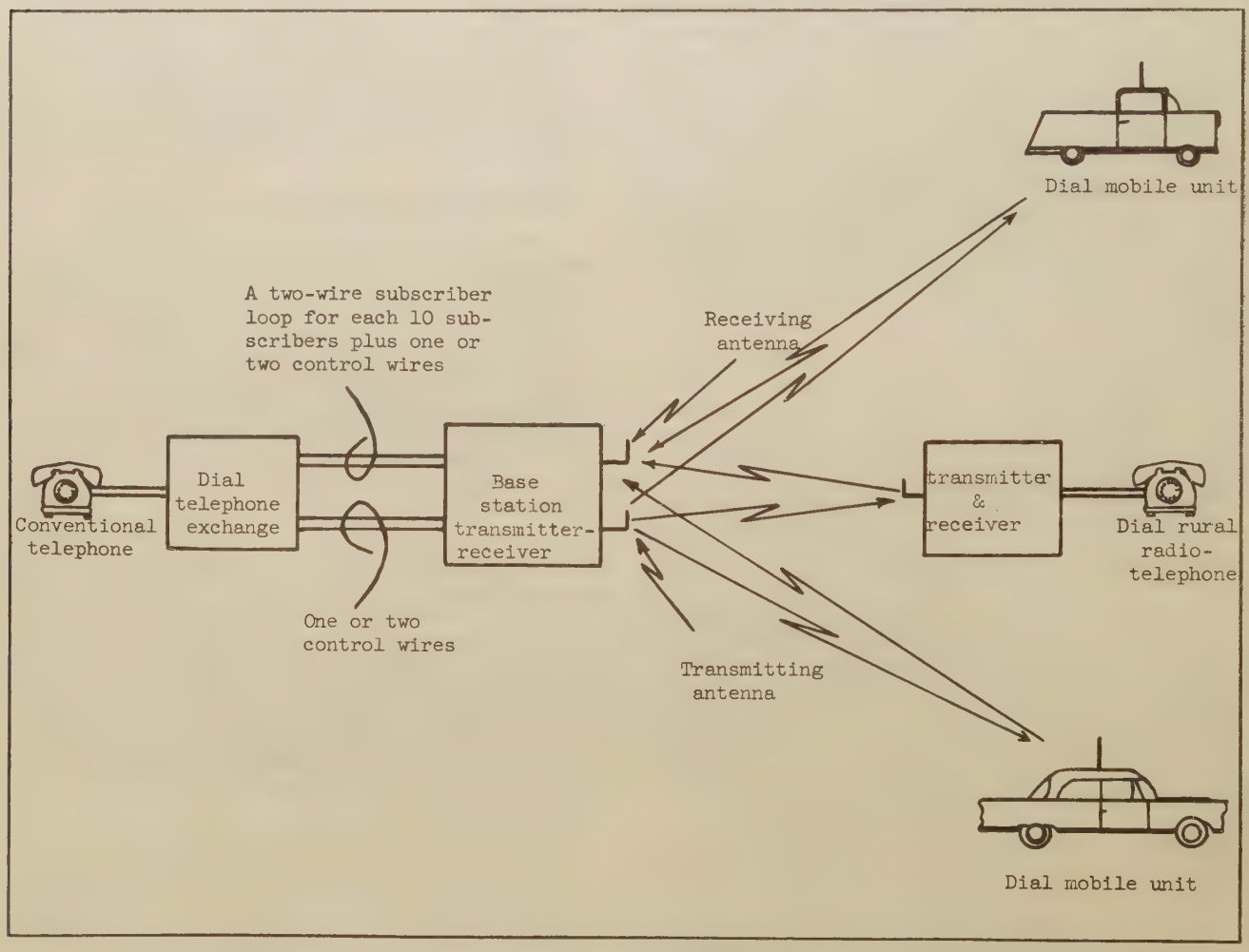

Fig. 1 - Schematic of a two-way radiotelephone dialing system connected to a dial telephone exchange.

Fig. 2 - Antenna installation at Amherst, Va. The receiving and transmitting antennas are high-gain Mark Products, Type C3150. The receiving antenna is on top of a 100 foot tower; the transmitting antenna is mounted about 24 feet below the receiving antenna and about 54 inches from the tower leg on which it is mounted.

Fig. 3 - L. John Denney, President of the Central Virginia Telephone Corp. operating the Motorola pushbutton radiotelephone installed in his automobile.

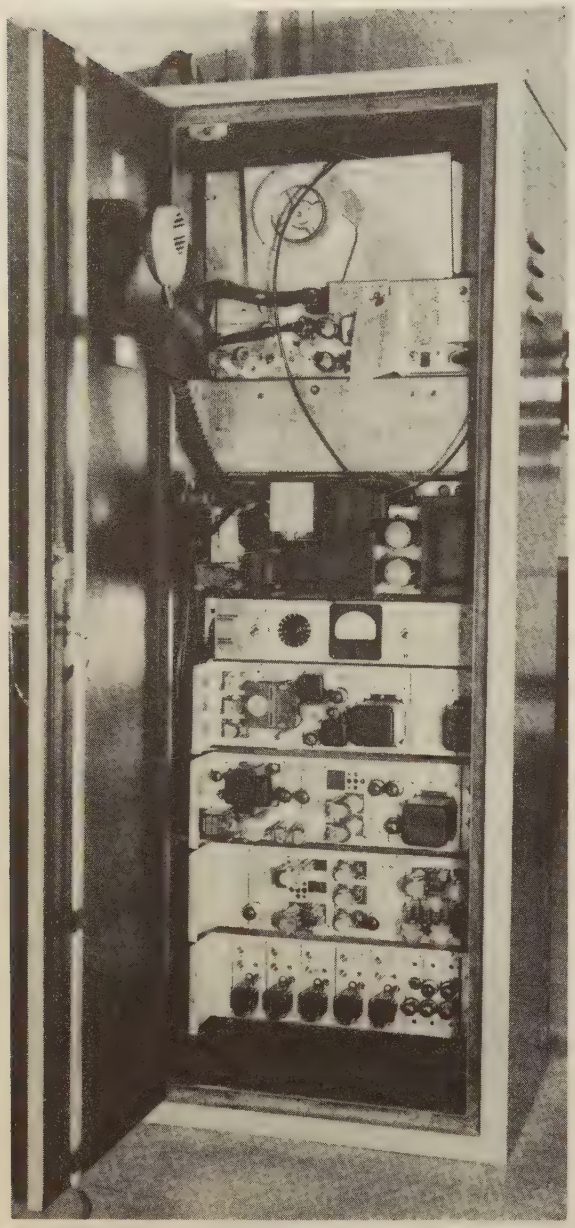

Fig. 4 - Front side of the base station at Amherst, Va. The lower four panels contain the applique equipment. Above the panels is conventional radio equipment.

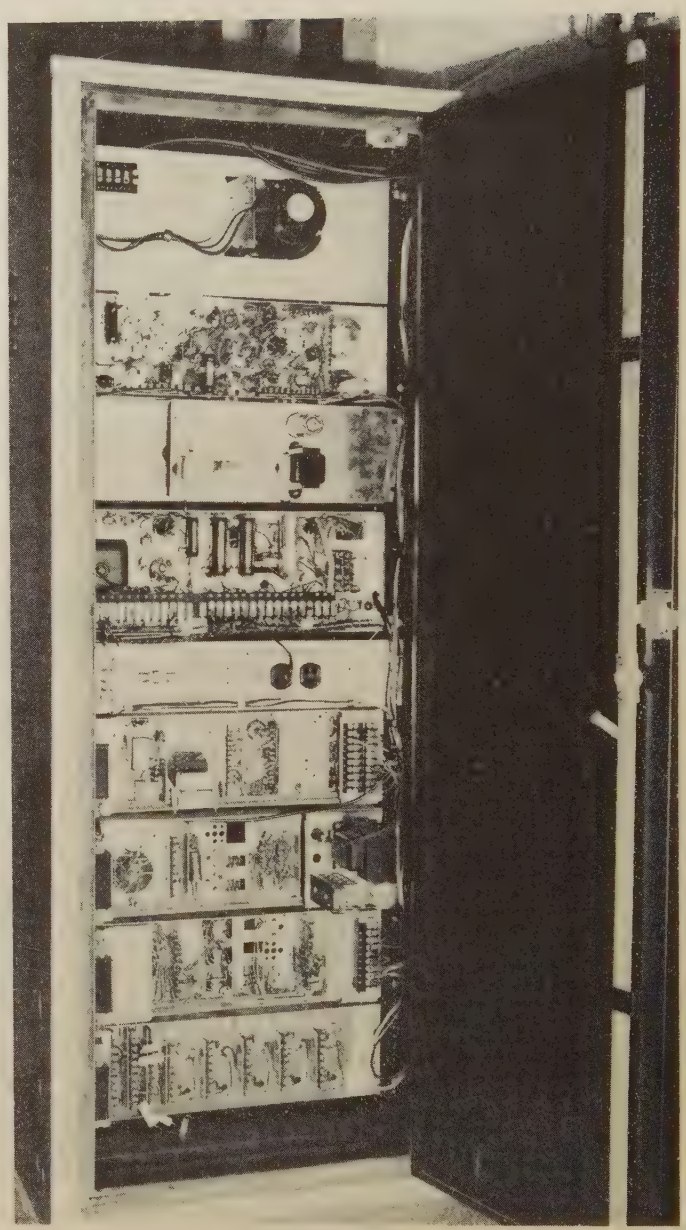

Fig. 5 - Back side of base station at Amherst, Va.

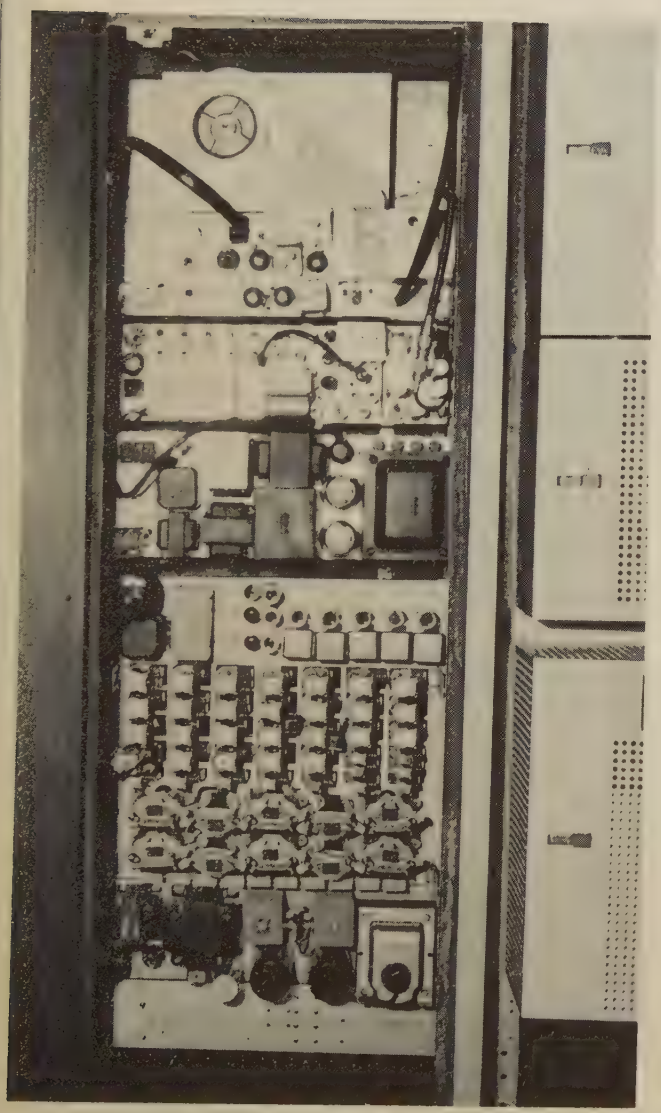

Fig. 6 - Front side of base station at Branford, Fla. A standard Motorola base station and transmitter is in the upper half of the cabinet; the applique equipment is in the lower half.

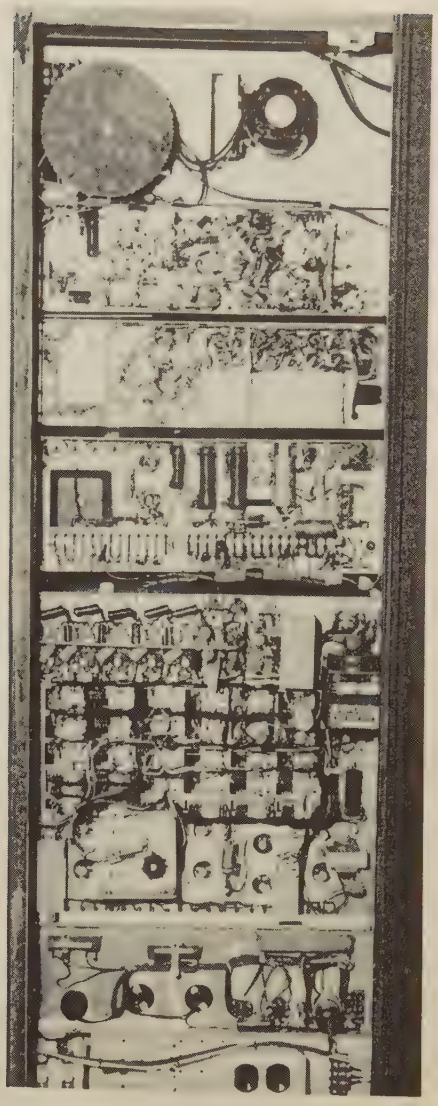

Fig. 7 - Back side of base station at Branford, Fla.

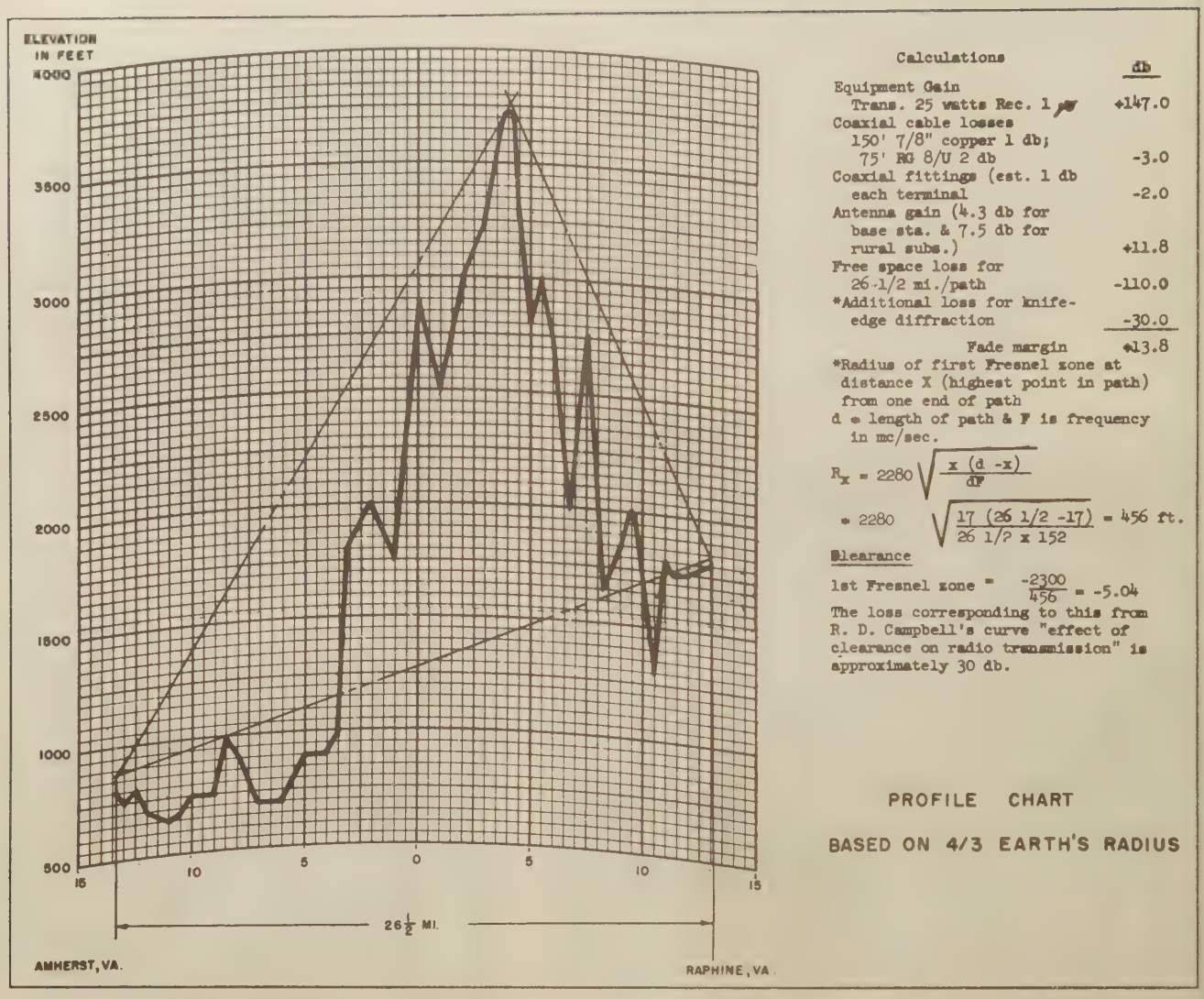

Fig. 8 - Path profile between Amherst, Va., and Raphine, Va.

Fig. 9 - Rural subscriber station located in the residence of Mrs. Jessie Steele, Raphine, Va.

Fig. 10 - Charles Fawcett, General Plant Manager, of the North Florida Telephone Co. operating the automatic electric mobile dial telephone installed in his automobile.

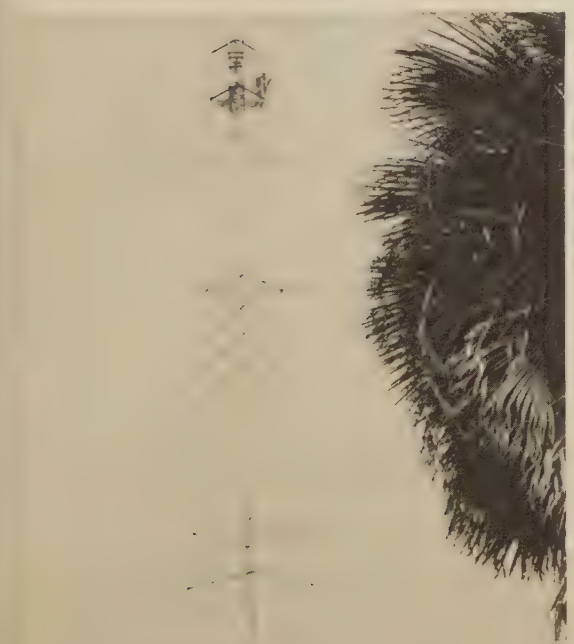

Fig. 11 (left) - Antenna installation on a 140 foot microwave tower at Branford, Fla. The antennas on this installation are also Mark Products, Type C3150.

Fig. 12 - Automatic electric rural subscriber desk set.

"DIAL DIRECT"
AUTOMATIC RADIOTELEPHONE SYSTEM

Ramsey McDonald
Richmond Radiotelephone, Inc.
Richmond, Indiana

Summary

The Dial Direct system enables radio units to dial any other mobile unit or any subscriber's land phone directly. Conversely, any land telephone subscriber may dial any mobile unit directly. The system is completely automatic and no operators are required. Through interconnections with other telephone companies, it is possible to make long distance toll calls from mobile units, simply by dialing a long distance operator, which is standard land telephone practice, however if used with a telephone exchange using an automatic ticketing device and inter-city direct toll dialing, the long distance operator would not be required. It is also possible to use the system on private radiotelephone systems such as MCC operations or any other mobile users with duplex channel assignments by the addition of a private telephone exchange connected to the terminal of the Dial Direct base equipment.

Introduction

For several years now, mobile radiotelephone service employing a mobile operator has been in general use. However, it is not as generally known that since March 1, 1948, a fully automatic radiotelephone system has been in operation in Richmond, Indiana. Around 1947, when the "New Look" in post-war automobiles was making its appearance to the public, a certain Lexington, Kentucky resident remarked to his friend "Look, Joe--there is one of those new cars and it has a dial telephone in it--wonder what they will think up next". It no doubt would not be news to Joe and his friend about dial radiotelephones today. It so happened that this car bore an Indiana license plate and actually was to be the first test unit of the system in Richmond, Indiana.

The basic termination apparatus has been expanded to include new developments and designs and a prototype sample incorporating these features has undergone extensive tests in the Richmond, Indiana system during the summer of 1957. This new system referred to as "Dial Direct" is being marketed by the Allen B. Du Mont Laboratories, Inc. of Clifton, New Jersey.

The system was designed to be compatible with automatic telephone exchanges without limitations as to the number of mobile units or rural radio subscribers stations connected. True, it would be ideal for each mobile subscriber to have his own private radio channel -- but of course this is not feasible since we must conserve spectrum space and therefore mobile radiotelephone service must be operated on a party line basis today. There is virtually no limit to the number of mobile units which could be incorporated in a single radiotelephone system, however, since only one conversation may be carried at a time, as a practical matter the number of mobile stations in a single system is preferably limited to 50-100 units. This does not place any limitation on the number of mobile code numbers that can be dialed through the system. It is highly important for an operating company installing such a system not to overlook the possibilities offered to the general public by use of "One Way Signalling", which facilities are available in such a system. One Way Signalling requires only seconds of "On air time", and although two-way subscribers for general service may limit a system to perhaps 50 to 100 units, the number of One Way Signalling subscribers can be increased by many times this number without serious impairment to service.

Approximately ten mobile subscribers may be required for economic reasons for a telephone company considering the installation of an automatic radiotelephone system, however the cost of operating personnel eliminated by the use of "Dial Direct" will no doubt pay for the termination equipment in slightly more than a six months period of operation. No longer will you be required to "load up" a channel to reach a break even point -- with automatic operation the overhead operator costs are eliminated. Automatic radiotelephone operation will no doubt be the answer to many telephone companies contemplating the addition of mobile radiotelephone or rural radio service to their present facilities.

Since various installations may require slight modifications to meet a specific requirement, the system is designed for flexibility to meet such applications and allows practically unlimited expansion without obsolescence.

Equipment

A block diagram is shown in Fig. 1 which illustrates a typical Dial Direct installation.

The base station equipment consists of a standard FM Transmitter, fixed FM receiver or receivers with separate transmit and receiving antennas since full duplex operation is used on the fixed station apparatus. Full duplex type of operation being optional in mobile or Rural Radio installations.

The heart of the system is the termination equipment shown in Fig. 2 and consists of a Meter-speaker-connector panel; Relay termination and test panel; Selector control panel and the power supply chassis. It can be housed in a floor mount cabinet or on an open 19" telephone rack-type floor mount. All relays are provided

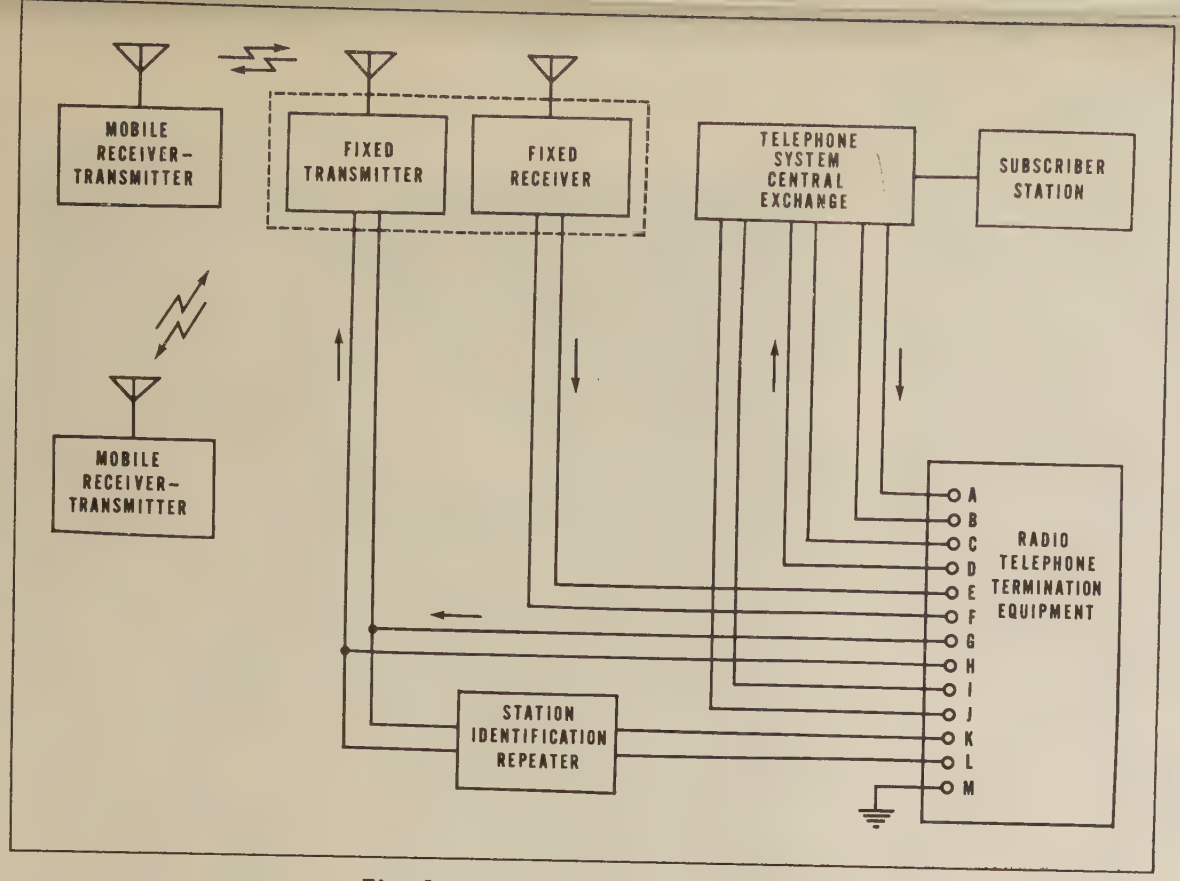

Fig. 1 - Dial Direct, block diagram.

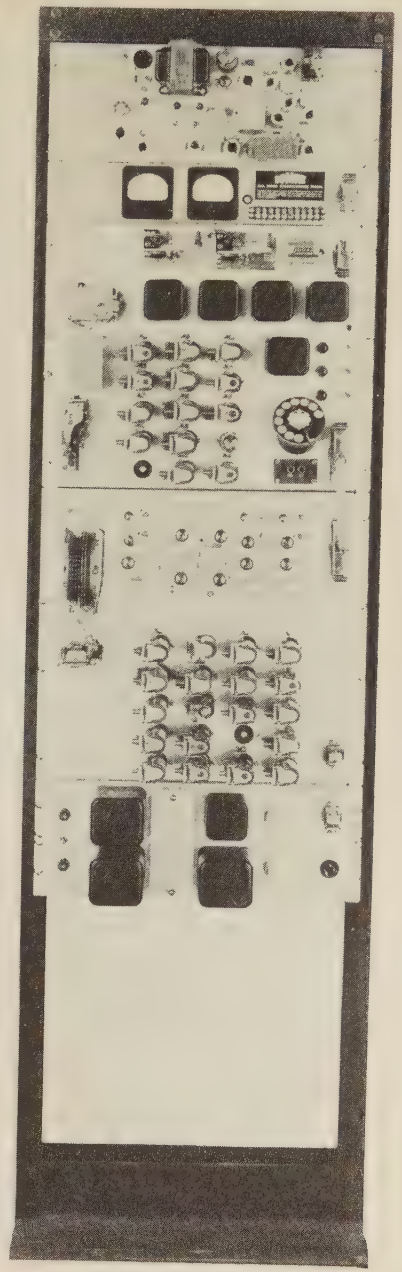

Fig. 2 (right) - Termination equipment with dust covers removed from plug-in telephone-type relays.

with dust proof covers and the interconnecting chassis are connected with Blue Ribbon quick release type fasteners on inter-connecting cable assemblies. Plug-in type telephone relays are used for ease of maintenance.

The termination equipment is interconnected to the base station transmitter receiver and the telephone exchange.

Fig. 3 - 5 illustrate mobile installations. The mobile units may consist of standard two-way mobile gear to which has been added the necessary selective calling equipment for use in vehicles, ships, or planes. For Rural Radio applications as well as perhaps certain shipboard installations 117 Volt AC transmitter receivers may be used along with the selective calling equipment.

The actual selective calling apparatus which is connected to the mobile station two-way transmitter-receiver equipment consists of a decoding device to actuate a bell, buzzer, horn and perhaps a call light which is connected to the receiver. Fig. 5 shows such a decoder designed by I. D. E. A. Inc. of Indianapolis, Indiana. A tone oscillator along with a telephone type handset and dialing assembly is connected to the mobile transmitter. Mobile units using the push to talk operation require one antenna while a dual antenna system is required for full duplex operation. Except in certain instances where more than one fixed station receiver is associated with the base station installation push to talk must be used on mobile to mobile calls, however all calls to or from a land telephone subscriber would permit full duplex type of operation on those mobile units so equipped. Simplicity of the selective calling gear reduces cost of radiotelephone units and keeps maintenance to a minimum.

Operation

Referring to Fig. 1 block diagram again, the connections to the Radiotelephone Termination Equipment are as follows — An incoming telephone pair to A and B connect to a selector level bank in the automatic telephone exchange.

This connection is used for calls made from a subscriber land telephone to a mobile unit. Only one telephone type relay is required at the telephone exchange equipment which will then provide a pulsing circuit to repeat digits dialed to signal a mobile radiotelephone unit and also provide a talking circuit for the audio portion. Terminal J provides a connection to the "C" lead to busy out this circuit when a mobile call is in progress. C and D connect to an ordinary subscriber telephone pair in the telephone exchange and this pair is used on calls from a mobile unit to a land telephone subscriber.

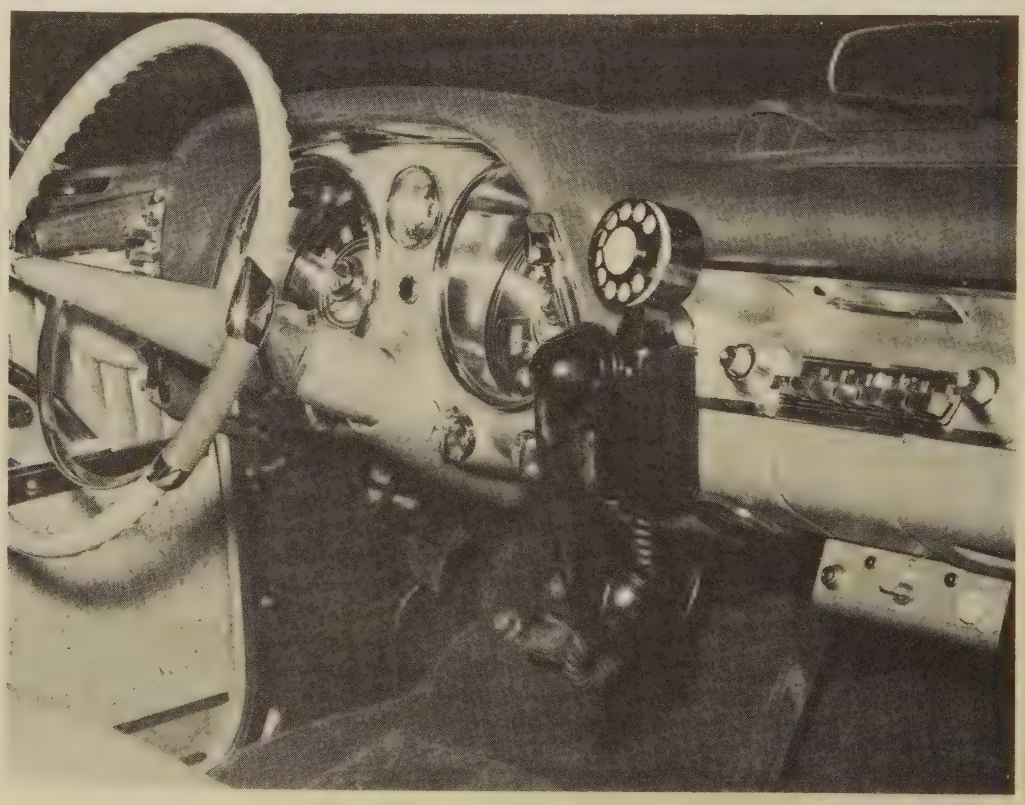

Fig. 3 - Radiotelephone dialing assembly using Western Electric hang-up for dash mounting.

Fig. 4 - DuMont mobile transmitter-receiver and mobile tone oscillator -- electrical communications secoder.

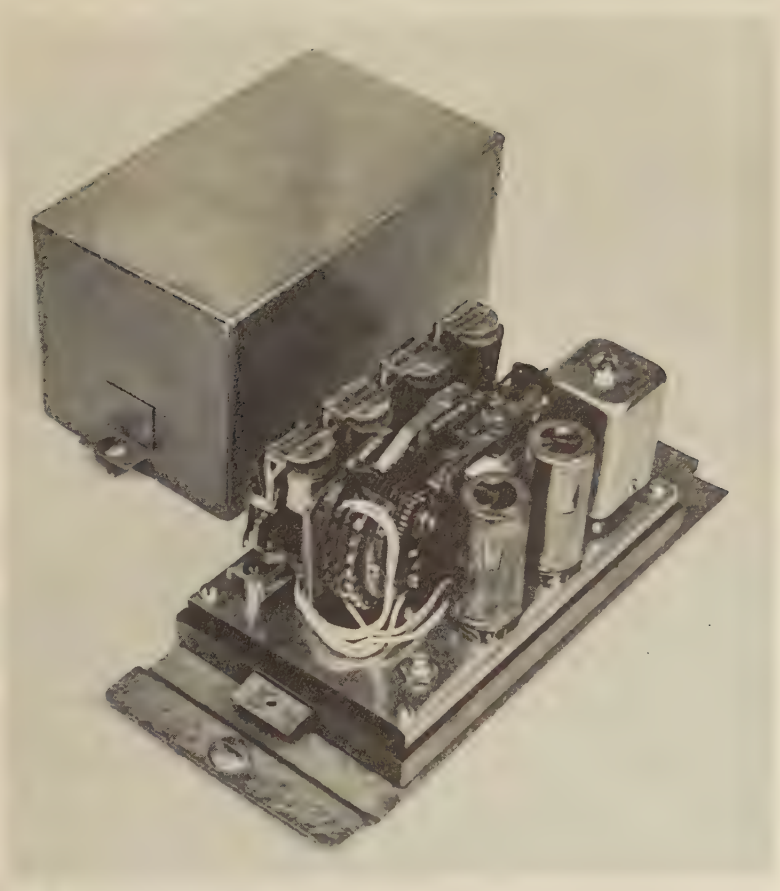

Fig. 5 - Mobile decoder using rotary step switch with telephone relays, 10,000 code combinations.

E and F connect to the fixed station receiver or receivers and is fixed tuned on the mobile transmit frequency. A carrier operated relay is incorporated in the receiver(s).

G and H connect to the fixed station transmitter and handle the control line voltage and audio.

I is an optional connection for trouble indicator circuit at some supervisory point if desired.

K, L and M provide means for connection of an automatic station identification repeater and is operated at the end of each call.

Land Telephone Calling A Mobile Unit

A telephone subscriber lifts handset and hears normal telephone dial tone. He then dials a typical mobile service number such as 166. The first two digits "16" switch through the telephone exchange equipment such as the second level bank and land into the radio termination equipment. The third digit or "6" then places the base station transmitter on the air and a distinct "radio dial tone" is then heard by the subscriber. This extra digit added at the radio termination equipment tends to eliminate to a large extent false calls being dialed into the system. It also prevents the base station from being activated by an accidental connection or short circuit in the line connecting to the telephone system central exchange. After the calling subscriber hears the "radio dial tone" he may then dial the number assigned to the mobile unit with which he desires to speak. At the called mobile unit, a bell or buzzer sounds indicating the incoming call and a call light is displayed. The call light is used to indicate the fact that a call had been received in the event that the mobile subscriber had not been in the vehicle when the call was made. The latter feature is optional but of course would be required for "one way signalling" service.

As soon as the mobile code number is dialed a distinctive interrupted tone signal is heard which will indicate to the calling subscriber that the mobile unit is being signalled. A master timer in the Radiotelephone termination equipment can be set for a predetermined time limitation on calls. As an example if a 3 minute limitation was desired the master timer might be set for 3 1/2 minutes, thus allowing 30 seconds for dialing and to answer and 3 minutes for conversation.

At the completion of a call, the party on the land line phone will cause the disconnect when hanging up telephone receiver. If phone was not hung up--then the master timer would disconnect the termination equipment and an alarm would be sounded at a supervisory point via connection provided on I terminal after the timer caused the disconnect. Upon completion of the call the station identification repeater would be activated momentarily. (Richmond off)

Mobile Unit Calling A Land Telephone

Mobile subscriber lifts handset from its hookswitch and listens to determine if the air is clear or in use by another subscriber. If clear, he hears a rushing noise, (receiver squelch rush) and may proceed to turn on his transmitter and dial his desired number. If in use, he must await the completion of the call in progress. Assuming a clear channel, he dials the number 9. This is used as a delaying tactic and permits the termination equipment to turn the base station transmitter on, sieze the line to the telephone exchange used for incoming calls, and place a "busy indication" on the outgoing line. It also eliminates the possibility of false operation due to random or spurious signals entering the base station receiver. After dialing "9", he then proceeds to dial the regular telephone number of the called land telephone. While this call is in progress, if another land telephone subscriber attempts to place a call to a mobile unit by dialing 166 as above he will hear a busy signal instead of radio dial tone and must place his call later.

Two timers are used in the radio termination equipment when calls are made from a mobile unit. The first timer usually set for 30 seconds will allow about 5 or 6 rings to the calling land phone, if no answer is received by that elapsed time the mobile operator may push the push to talk button again for an additional 5 or 6 rings. Should the number dialed be busy then the normal busy tone from the telephone system exchange would be heard and the timer disconnects the circuit. Assuming the called land phone subscriber did answer, then a polarized relay disconnects the 30 second timer and again the master timer (3 minutes) is then in the circuit. Upon completion of the call before the 3 minute limitation the polarized relay disconnects the system when the land line phone is disconnected. Again the station identifier repeater would be activated. (Richmond Off)

Mobile To Mobile Call

Up to this point the basic system functions with perhaps a few refinements have been the same as the automatic radiotelephone system in use in Richmond, Indiana for nearly ten years, however, the next type of call that may be handled through the "Dial Direct" system is distinctly new and permits direct mobile to mobile dialing using the base station equipment as a repeater. The mobile units are therefore not limited to the range over which they could communicate unassisted but are enabled to communicate over the greater range made possible by the repeater function of the base station transmitter and receiver.

A distinct feature of the Dial Direct system is the fact that on mobile to mobile calls the telephone central exchange can be completely out of service due to a breakdown but emergency crews equipped with radiotelephone can still call between mobile units. Another feature of the

system is that the master timer is not in operation on mobile to mobile calls or toll calls from a mobile unit.

A mobile call is placed as follows: The mobile subscriber initiates the call in the same manner, as if he were dialing a land telephone, but instead of dialing "9", he dials "9-9". This second digit may be other than "9" but is a number that becomes lost in the telephone exchange and causes a busy to appear on the incoming telephone pair and disconnect on outgoing line. He then dials the number of the desired mobile unit and conversation ensues.

The first digit dialed after the seizure of the base station, is checked. This number could be more than one digit, however, most smaller exchanges do have a dummy number available. One of two relays operate after the first digit is dialed. If the call being made is to a land phone then one of these relays lock up, however, if the mobile to mobile number is dialed, then the other relay locks up and the RF carrier is modulated by the same "radio dial tone" that is used when a land phone calls a mobile unit.

Once the dialing is completed on a mobile to mobile call the presence of the next R.F. mobile carrier will release the "radio dial tone" and the circuit is ready for conversation. It is only necessary for one of the mobile units to transmit each 30 seconds once to hold the connection. The 30 sec. timer will automatically disconnect after call is completed. Power utility companies using this service find such a feature very desirable for emergency switching operations.

Conclusion

It is believed that the lower operating costs of automatic radiotelephone service will provide necessary facilities whereby mobile radiotelephone service will be made available in many more communities throughout the country. Great interest has been evidenced by many of the smaller telephone operating companies for this type of communication which will not only be of benefit to the general public but will supplement telephone maintenance operations for the operating companies who may also gain the many advantages by the use of two way radio.

VEHICULAR TRANSMISSIONS

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Summary -- Available quantitative field strength data over irregular terrain is reviewed* and interpreted for its usefulness in vehicular systems engineering. Included are terrain effects vs. frequency, antenna heights and distance, field strength fluctuation, and man-made noise and its effects on vehicular reception at various frequencies. The usefulness of this data and its relationship to vehicular field usage is discussed.

Vehicular transmissions always take place over irregular terrain so that the ordinary method of calculating propagation attenuation over plane earth, smooth earth, and simple diffraction edges becomes unsatisfactory. As one moves about in irregular terrain in a vehicle the received signal is characterized by a slow variation which depends on the major features of the terrain and on distance, and by a fast variation about the median in a small sector which is independent of the transmission distance but is dependent on the speed of the vehicle and on the frequency of the transmission.

In the practical sense, the systems engineer is interested in knowing how well his equipment will be able to service an area, or how well his equipment will cover many areas in a very large area. Some of these areas may typify smooth earth while other areas may be highly mountainous; all others will be in between in terms of surface irregularity.

Field strength data over irregular terrain have been assembled by the FCC and are based on survey data taken by commercial organizations in various parts of the country including New York, N. Y.; Washington, D. C.; Cleveland and Toledo, Ohio; Harrisburg, Easton, Reading, Pittsburgh, and Scranton, Pa.; Kansas City, Mo.; Cedar Rapids, Iowa; San Francisco, Calif.; Bridgeport, Conn.; Nashville, Tenn.; Fort Wayne, Ind.; Richmond and Norfolk, Va.; and Newark, N. J. In each of these locations, a number of radials was investigated. In the uhf range, 288 to 910 mc, 804 miles on 63 radials are represented in the data. In the vhf region, 50 to 250 mc, in the order of 1,400 measurements, consisting of continuous data analyzed over one mile and two mile sectors are included in the data. The method of measurement, while not the same at all locations, falls into three categories: continuous mobile recording sampling every 0.2 miles, spot measurements properly weighted so as to be considered unbiased, and clusters of measurements.

*Egli, J. J.: "Radio propagation above 40 mc over irregular terrain." Proc. IRE, 45:1383-1391 (Oct. 1957).

The measured field strength data over irregular terrain were compared with what one could expect over plane earth rather than smooth earth, since the best median field strength data fit for distances up to 30 to 40 miles shows that the inverse distance square trend for plane earth is better than the smooth earth field, at least for low antenna heights. Therefore, the median field at a given frequency can be described by the theoretical plane earth field intensity less than median deviation therefrom. This median deviation data from the theoretical plane earth field, called terrain factor, is shown in Fig. 1. The straight line in this figure very nearly passes through all the FCC data, and it will be noted that the field strength varies inversely with the frequency and is independent of distance. The intersection of this line with the theoretical plane earth field strength is at 40 mc, so that the variation with frequency is with respect to this frequency.

The theoretical plane earth field expression is given by:

$$E = \frac{h_t\, h_r\, f}{95\, d^2}\sqrt{P_t} \qquad (1)$$

Statistical information is:

$$E_{50} = \frac{40\, h_t\, h_r}{95\, d^2}\sqrt{P_t} \qquad (2)$$

Equation (2) shows that nature herself, by interposing terrain features, has essentially placed in juxtaposition the frequency dependence of the field strength above 40 mc over plane earth. Thus, while the theoretical received field strength over plane earth increases with frequency, the median received field intensity above 40 mc over irregular terrain is independent of frequency. It is interesting to note that if one determines from diffraction theory the depth of hills which will result in the median loss of Fig. 1, the statistical irregular terrain can be conceived as hills with a depth of about 500 feet.

Terrain-Frequency Dependence

If one explores the data in terms of the distribution of received field strength over irregular terrain, one finds that the over-all terrain distribution, when plotted in decibels above the theoretical plane earth attenuation, is log-normally distributed. Thus, on probability paper, the terrain distribution will appear linear and may be described by its median value and standard deviation, as shown in Fig. 2. The terrain distribution of field intensity in the vhf band, taken at a center frequency of 127.5 mc appears to

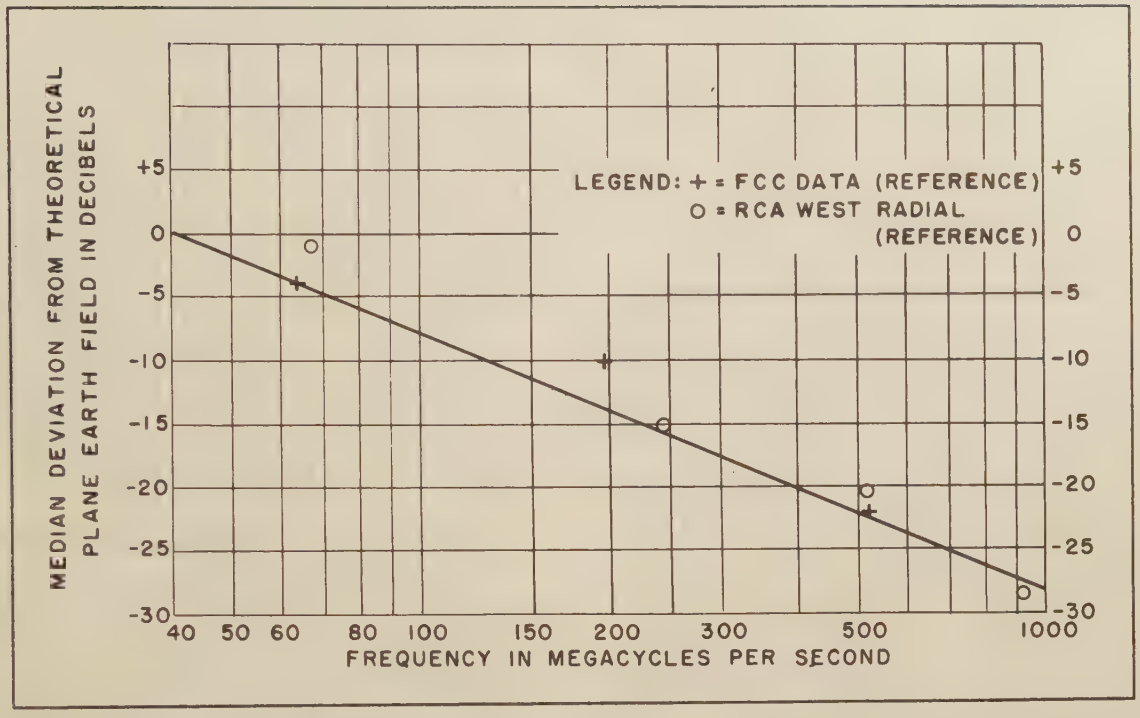

Fig. 1 - Median terrain factor for fixed-to-vehicular or mobile service.

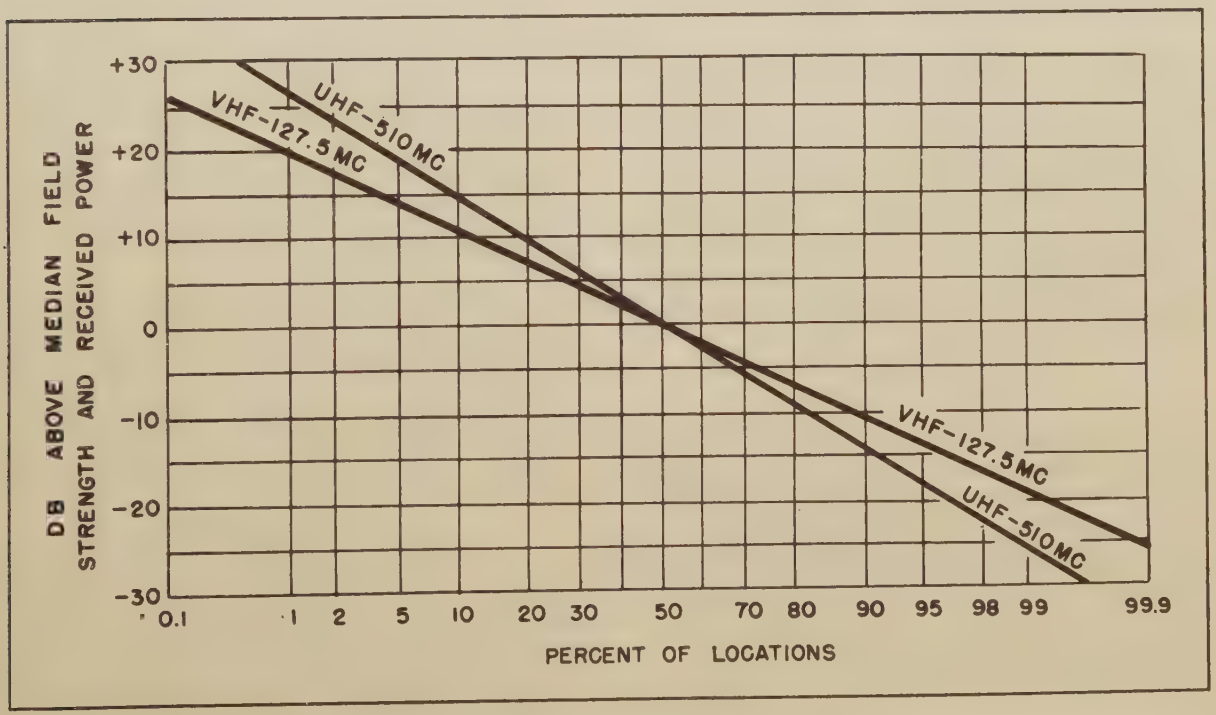

Fig. 2 - VHF and uhf terrain distribution.

have an over-all standard deviation of 8.3 db, while the terrain distribution of field intensity in the uhf region centered around 510 mc appears to have an over-all standard deviation of 11.6 db.

Of course, the median deviation from theoretical plane earth field is displaced 12 db by the terrain factor for the two frequencies (Fig. 1). From this standard deviation data, Fig. 3 has been prepared which permits the determination of the correction factor to the E_{50} field strength when the received field strength to other than the 50 percentile location is desired.

Terrain-Transmitting Antenna Height Dependence

The transmitting antenna height, used in conjunction with the data, is defined as the height above the median, two to ten mile terrain level. This rule has not proven as reliable as one might expect since it does not take into account the terrain within two miles or beyond ten miles. For all practical purposes, the data confirmed that the received field strength increased linearly with transmitting antenna height. Transmitter height-gain tests made around New York City seem to indicate that in poor service locations the effect of transmitting antenna height increase is somewhat less than one would theoretically predict, in median or 50 percentile locations the height gain would approximate the theoretical expected height gain, and for good service locations the height gain would be somewhat more than the theoretical.

Terrain-Receiving Antenna Height Dependence

Receiving antenna height is the effective height above local terrain. The data do not appear to support any clear-cut variation of field strength with change in receiving antenna height. For receiving antennas which clear surrounding terrain features, the height gain appears to be linear; for receiving antennas which do not clear the surrounding terrain features, no orderly pattern is discernible. However, test results analyzed statistically show that in the 6 to 30 foot category, the field strength appears to support a square root height-gain variation. Above 30 feet the height gain is linear.

Indigenous Noise

While the relationship between received signal and frequency over irregular terrain has been fairly well covered, another important power balance factor is the establishment of the noise level of the receiver, or the signal required to assure satisfactory communication. Noise in the frequency range above 40 mc is mainly caused by man-made noise. The general classifications are rural, suburban or small town, and urban noise. Cosmic noise is still present up to 100 mc. Collectively, this noise can be termed indigenous noise.

The extent to which this indigenous noise acts upon a receiver is shown in Fig. 4. Two curves have been drawn for suburban noise, since the material for these curves have been drawn from two separate references. The lower suburban noise curve is representative of the median indigenous noise experienced in areas suburban to New York City, with extrapolated data shown by the dotted portion of the curve. The urban noise data taken from these same two references dove-tailed into the same curve. The dotted curve represents the noise figure of a currently well designed receiver and is shown only to give the figure perspective.

The difficulty in the use of these noise curves lies in just what level of noise should be applied in systems design work. Unfortunately, indigenous noise data weren't collected along with the field strength data. If this had been done, a distribution of the magnitude of noise over the areas in which the field strength data were taken would have been available. It would appear that equipment designed for general use should at least consider the lower suburban curve of Fig. 4, with the thought that in urban areas advantage might be taken of the height gain in these areas.

Terrain-Small Sector Field Strength Variation

As noted earlier, there is a fine amplitude variation about the median in a small distance or area which is independent of the distance from the radiation source and is Rayleigh distributed. The amplitude distribution is the same at all frequencies, indicating that the range of constructive and destructive phase interference or standing wave effects is complete. However, the number of constructive and destructive interferences increases in a given distance or area with frequency. Tests conducted in the Phoenix, Arizona, area indicate that the average vehicle travel between these fine signal minima is one wavelength in free space, while in the direction away or toward the radiation the distance between signal minima is the free space half-wave distance. With this information, in vehicular service the small sector amplitude fluctuations in received carrier level will increase in rapidity with frequency and the speed of the vehicle.

The nomograph of Fig. 5 shows, for example, that at 150 mc the received field in a vehicle traveling at 40 miles per hour in the direction of transmission would have an average fluctuation rate of 18 cps. For vehicular service, this is the fluctuation rate which would have to be considered in the design of AGC circuitry, with the audio or intelligence pass band designed above this frequency.

Another characteristic of these variations (Fig. 6) is that the higher the frequency, the steeper the fall and rise in field strength. In general, the variations appear to be deeper, with the time between rise and fall smaller. One can also raise the question of what is meant by median and design point at the acceptable lowest S/N ration of the system. For example, at 40 miles per hour, riding through the fine grain variations at uhf, one would not lose a syllable of speech, but at vhf syllables would be dropped and result in garbled speech.

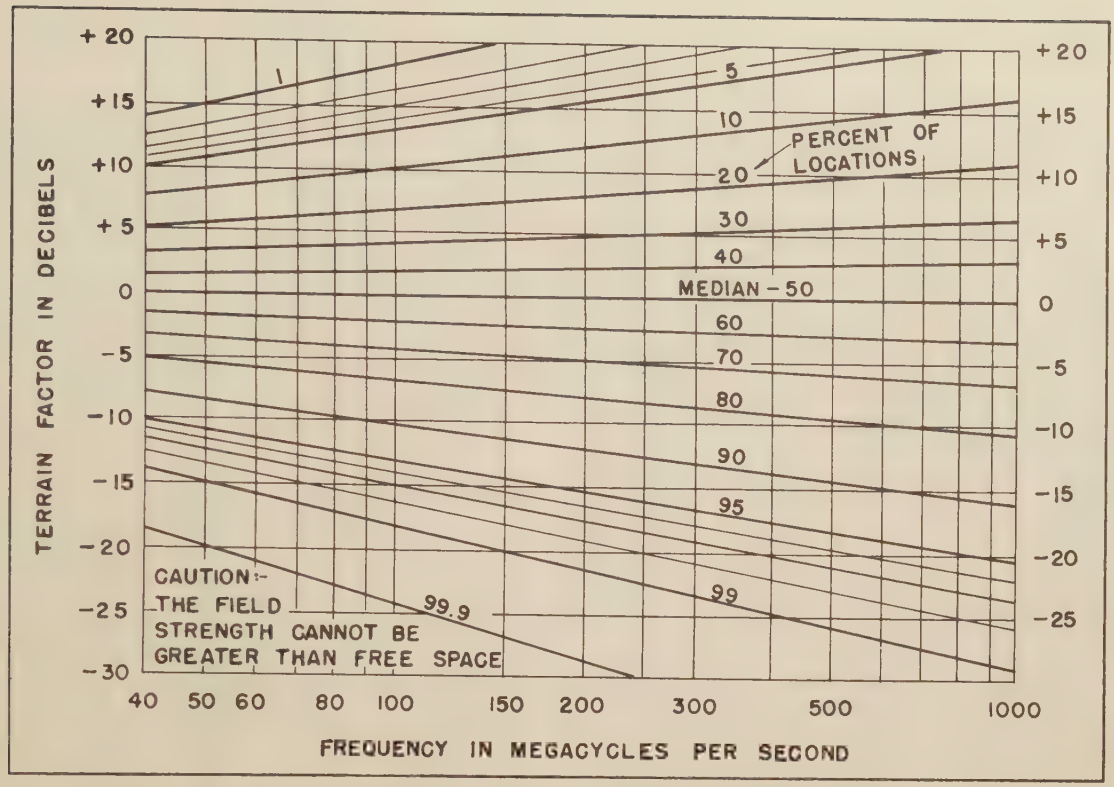

Fig. 3 - Fixed-to-vehicular or mobile service field strength terrain factor.

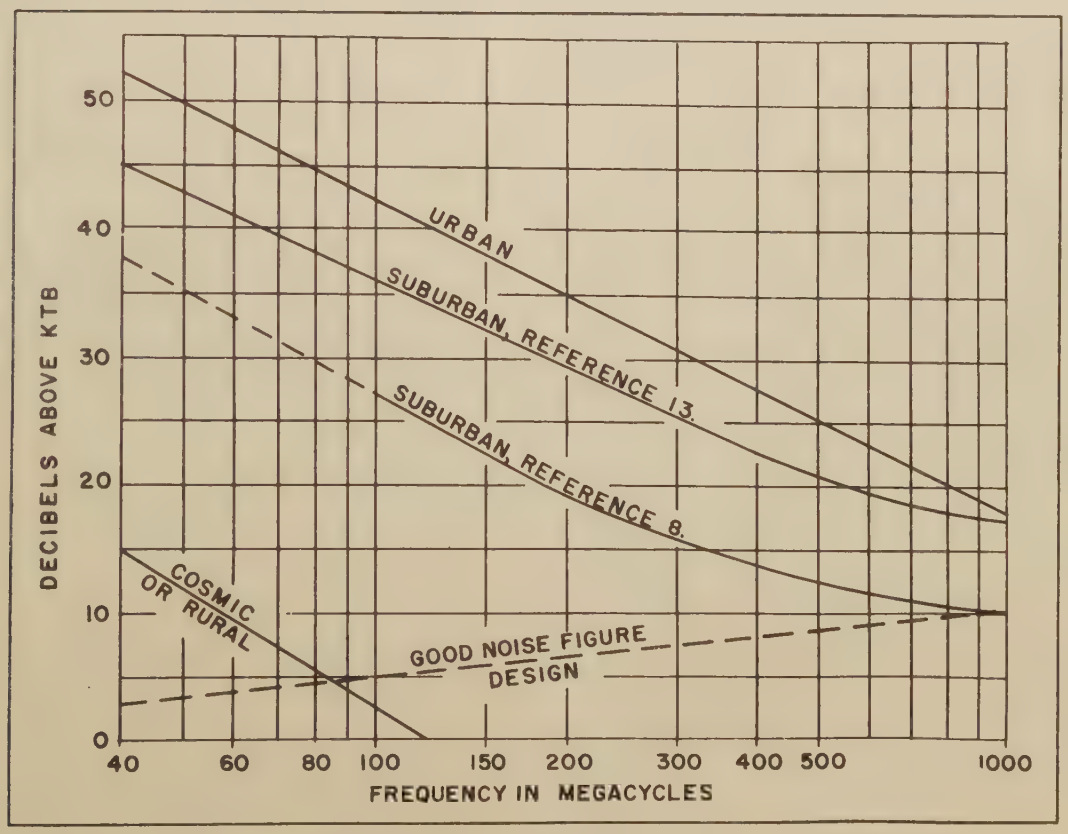

Fig. 4 - Median indigenous noise.

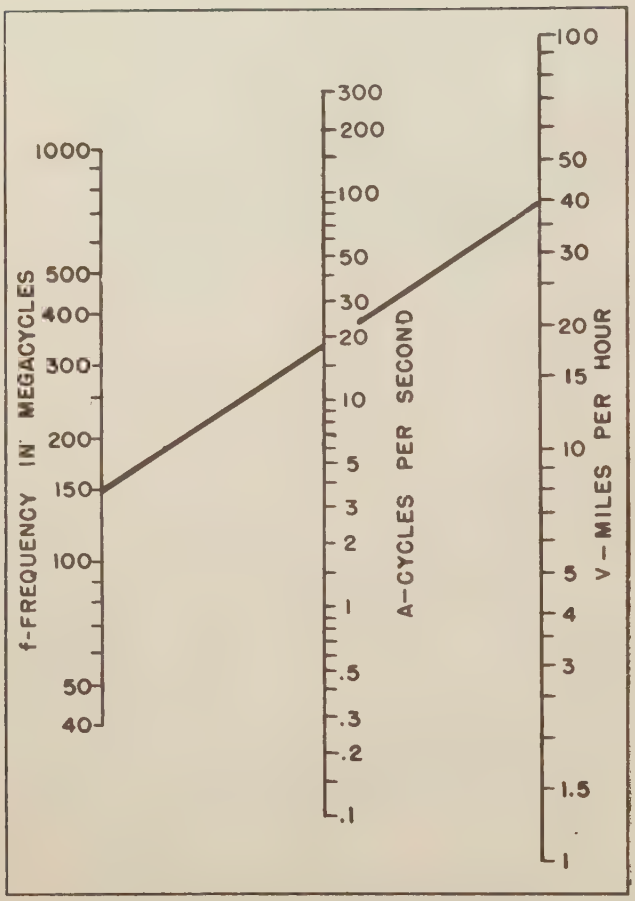

Fig. 5 - Fluctuations in vehicles.

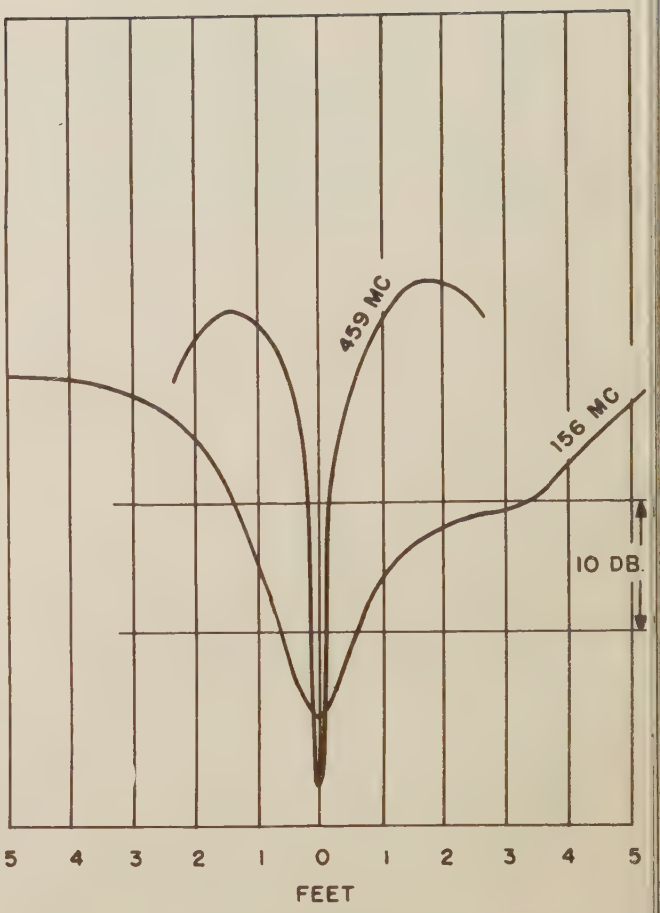

Fig. 6 - Maximum small sector variation.

In Fig. 3, suppose one arbitrarily lifted one antenna of the system to twice the original height; then the service in the area would favor the lower frequencies. Conversely, however, if it has been determined that the coverage area is about the same at vhf and uhf, then a drop in antenna height of one-half, height gain drop of 6 db, would reflect better service at uhf than at vhf. Again, suppose radiated power is cut by 10 db on two systems, one at vhf, the other at uhf, both supplying about equal service; then the vhf would be the more effected.

As further example of the use of Fig. 3, assume two systems, one at vhf and the other at uhf, giving comparable service at 5 miles. The question is, which one gives better service at 10 miles? Since doubling the distance is the same as a 12 db drop in field strength at 10 miles, the uhf region will provide the better coverage.

ADDRESS BY WARREN E. BAKER, GENERAL COUNSEL,
FEDERAL COMMUNICATIONS COMMISSION

My feeling when I was asked to address the Professional Group on Vehicular Communications of the Institute of Radio Engineers was a good deal like that of the man who saw his mother-in-law driving his brand new Cadillac off the edge of the cliff--I am full of mixed emotions. I always like to explain to non-lawyers the necessity of having lawyers around. On the other hand, I am always a little bit concerned when it comes to talking to experts about their own field of endeavor.

I am sure that time and time again, in publications and in speeches, you have heard public officials talk about the necessity for having a central regulating agency for radio because of the limited spectrum space, and the description of this space generally sounds as if the spectrum consisted of a specified number of tubes from one place to another, through which communications could be forced. I must confess that despite the fact that I first put together a receiving set in 1927, and have had some familiarity with radio transmission and reception ever since, I, too, during most of my adult life prior to coming to the Communications Commission thought loosely that we had a fixed amount of spectrum, and it was primarily a question of how we divided the pie. But I now know that I grossly underestimated the ingenuity of the engineers.

In the four years that I have been with the Communication Commission, you gentlemen--the people who design, develop and produce radio equipment, or make use of the equipment--have demonstrated to me that this limited spectrum is as flexible as a rubber balloon. At one time, for example, people thought that frequencies above 30 megacycles were completely useless. Even the most naive of us, when we look at a television set, know how mistaken this idea was. But it took the engineers to demonstrate that frequencies of this magnitude could be utilized for communication.

Not too long ago, few people believed that frequencies above 1000 megacycles would be useful for much, but technical progress has demonstrated that this may also be one of the more useful portions of the spectrum. This expansion by going higher and higher in the spectrum and in adapting these frequencies to communication needs is similar to the explorations of Columbus and others, who did not create any new land, but merely pushed the frontiers beyond what was previously known.

The thing that impresses me, a lawyer, is the ability of you engineers to find ways of increasing the amount of usable spectrum and, at the same time devising ways and means of handling more communications in a given amount of spectrum space. I refer, of course, to the constant improvement, through technological progress, in the amount of communications that can be squeezed through a specific number of kilocycles of spectrum space. First came the use of directional antennas to increase the number of user transmitter locations, then development of more stable equipment through crystal control oscillators, the development of single side band, meteor burst, forward propagation scatter techniques, and a host of other technological developments to improve the usefulness of the spectrum space.

By means of these and countless other engineering advances, you have made possible our present fabulous communications system in this country. It is inconceivable that this system could have been accommodated in the 30 megacycles which we once thought were the limits of the useable radio spectrum and the channel spacing we once thought was necessary.

Of course, I am not competent to forecast the outer limits of this elasticity which you have provided. But as one of the lawyers having to participate in the Government's decision as to how to divide the pie, in the face of an ever increasing demand by new and old users for an opportunity to join in the communication field, I appreciate the efforts of the engineering profession making the pie bigger. Nevertheless, despite the best efforts of the engineering profession, the amount of useable channels of communication which we have available, just like the average family income, never seems to be sufficient to satisfy all the demands upon us. And thus we have the necessary evil--a regulatory authority which must decide between conflicting demands, and, on some just and equitable basis, determine who shall and who shall not use this spectrum space, and, more important, what portion of it shall be given to each group. And here is where we lawyers come in.

I suppose you engineers feel that you can never escape the lawyers. You

may be right about that. Some day soon you men of science will doubtless devise a means of travelling to Mars. And when you arrive, there will probably be a Martian lawyer waiting to serve you with a summons for trespassing.

But I think you will agree that we lawyers do have some usefull purpose to serve in the radio field. We learned back in the 1920's that there must be a legal and orderly way to divide up the spectrum and regulate its use. Congress provided the necessary mechanism--first in the Radio Act of 1927, and then in the Communications Act of 1934.

I might add that when the Communications Act was enacted, it was not contemplated that it would have to apply to the type of shared services which are the major users of vehicular communications and which have largely come into being since 1945. The drafters of the Communications Act had in mind primarily broadcast, common carrier and certain safety services. As a result there are several provisions of the Act which are not particularly suited to shared industrial services. For example, I shudder to think of the chaos that would result if the protest procedure in Section 309(c) of the Act was widely used in such services.

Under the Communications Act, the FCC is given very broad regulatory powers. In addition to its licensing authority, it has authority to classify radio stations, prescribe the nature of service to be rendered by each class, and assign bands of frequencies to the various classes of stations and to the individual stations. In exercising this authority the Commission must adhere to the requirements of due process of law. In general terms, due process means that the Commission cannot act arbitrarily and must respect the rights of all groups and individuals in carrying out its functions. But the requirements of due process are not always the same. They vary according to the type of proceeding that is being conducted.

In some fields, such as broadcasting, the Commission allocates a band of frequencies to a particular service and then determines which particular person shall utilize each particular frequency and at what location and with what power. Where the use of a frequency at a particular location or in a particular area is going to be exclusive and several persons desire to use the frequency, the law requires that the Commission choose between the competing applicants through a long and laborious procedure known as adjudication.

Generally speaking, this complicated procedure is not of much importance to the vehicular radio service because exclusive use is seldom authorized in this field, except in certain safety services where sufficient frequencies are maintained so as to avoid a contest between potential users. In such a shared service, the Commission sets eligibility standards through the rule making process, and all those who meet these standards are eligible to be licensed and operate on a shared basis. Thus, for example, in some services only certain industries are eligible, and in some services the Commission has limited eligibility by means of the metropolitan area concept and the yard area concept.

The vehicular radio services are, of course, shared services. Since rule making is the means by which frequencies are allocated to such services and also the means by which eligibility and operating rules are prescribed for them, I am certain that this is the procedure which you are most interested in knowing something about.

As a little background it might be desirable to consider why we have the particular kind of procedure we do, and what rights and opportunities it gives to those who are interested in using part of the spectrum space. Prior to the adoption of the Administrative Procedure Act in 1946, the Communications Commission had a relatively free hand in determining who could use what portion of the spectrum. Broadly speaking the Commission could more or less just make up its mind that the police or the forestry industry or the petroleum industry needed a certain number of kilocycles in a particular portion of the spectrum, announce that it was available for their use, and that was that. Moreover, prior to the Administrative Procedure Act, the same procedure was applicable to rules governing the kind of emissions, the width, the power, the engineering standards as to how to measure them, how communications will be handled, the standards of eligibility and many other matters.

To those who obtained what they wanted, this pre-Administrative Procedure was probably satisfactory. Moreover, it was relatively uncomplicated and speedy. But to those who found themselves in a "have not" position, it was not a particularly happy procedural situation.

Passage of the administrative Procedure Act brought about some basic changes in this rule making procedure. In effect, Congress established some

ground rules for administrative agencies to follow in carrying out their rule making functions.

And, just what does the law now require with respect to the adoption or modification of rules? It requires basically four things. One is that the agency must issue a notice of an intention to adopt rules, setting forth the proposal with sufficient definiteness to apprise people of what is contemplated. However, the exact text of the proposed rules need not be set forth. The notice must then be published in the Federal Register. Second, the Act requires that an agency provide an opportunity for persons who feel they are interested to comment on the desirability of adoption of the rule, and to suggest changes or modifications of the proposed rule. Third, it requires the Commission to formally adopt its rule after considering all comments, if it decides that the proposal is in the public interest, with a short concise explanation of what the rule is intended to accomplish. And fourth, the agency must publish the adopted rule at least 30 days prior to its effective date. In short, the Administrative Procedure Act requires that you first be notified of the proposal; second, be permitted to comment on the merits of the proposal; third, be told the decision on the proposal and what its intention is; and fourth, that you be given 30 days notice before the rule becomes effective.

I should like to point out that there are exceptions to these requirements. For example, they do not apply to an agency's procedural rules. Moreover, notice or rule making and comments may be eliminated if the agency for good cause finds that they would be impracticable, unnecessary or contrary to the public interest. But when any of the exceptions are used, the agency is required to set forth in writing its reasons for not following the normal rule making procedure.

You are all acquainted, I'm sure, with a recent instance in which the Commission found it necessary to invoke one of the exceptions provided by the Administrative Procedure Act. I refer to the Commission's order of September 19, 1957, which without notice or comments, re-allocated two 40 MC frequency bands from non-Government to Government use. This was done because the Government had urgent national defense requirements to use those bands for ionosheric scatter circuits. This order had a direct impact on many vehicular communications systems in which all of you are interested, but I am sure that you will agree that under the circumstances the Commission had good cause for taking the action it did. Indeed, the Commission would have been seriously remiss in its duties if it had done otherwise.

I think that to fully understand what rights you have and what rights you do not have in the rule making process, that process should be compared to adjudicatory procedure. In both adjudication and rule making, the person affected is entitled to be notified of what is proposed to be done. In both, the opportunity to be heard is guaranteed, but the opportunity to be heard is quite different in the two kinds of procedures. And this is a most significant difference. For when we lawyers speak of the "opportunity to be heard" we mean different things at different times. This is an example of the way lawyers confuse engineers--in the same way as engineers have been known to drive lawyers to distraction by using that simple term "interference" to mean things in varying circumstances.

In adjudication, the person concerned is entitled to have a formal record compiled before either the Commission or a hearing examiner with the introduction of evidence and an opportunity to cross-examine witnesses. In effect, a sort of administrative trial is conducted. In addition, in adjudication, a decision must be based upon the specific record compiled, an opportunity must be given to file proposed findings of fact, conclusions of law, and, if there are intermediate decisions, exceptions to those decisions. Oral argument is also required to be held before the full Commission. Moreover, the decision must ultimately show the findings of fact and conclusion of law and rulings on the exceptions. This is indeed an ample, technical and quite often lengthy proceeding.

By contrast, in the rule making process, while you are entitled to file comments with respect to the proposed rule, persons are not, except in unusual cases, entitled to an evidentiary hearing, a formal record, nor even a decision which rests only upon the record compiled. For in this area, the agency is entitled to rely on facts within its own knowledge or which are contained in its files, in addition to those contained in the comments of interested parties. Furthermore, the rule making process does not require that there be proposed findings, exceptions, briefs, argument, or other technical right of adjudication, and the decision of the agency does not have to make factual

findings and conclusions and ruling on all the specific proposals and comments. It merely has to indicate that the various proposals and comments were considered, an ultimate decision reached that is not arbitrary or unreasonable, and then explain the rule and its intent.

This does not mean that where an agency feels it is necessary, any or all of the procedural aspects normally associated with adjudication can not, in the Commission's discretion, be given. It merely means that persons affected by rule making are not entitled to these procedural steps as a matter of right.

I should like to call your attention to still another type of proceeding which does not strictly fit either the adjudicatory or rule making category. I have reference to legislative type inquiries such as the Commission is conducting with respect to the microwave portion of the spectrum, and concerning frequecies between 25 and 890 megacycles

In these proceedings, the Commission is endeavoring to gather all possible information with respect to broad areas of its regulatory responsibility, which is in contrast to rule making proceedings, where some proposal to change specific Commission rules is under consideration. These inquiries provide a means whereby the Commission collects information which will assist it in charting its rule making course. They are of importance because they furnish the raw material out of which the Commission will fashion concrete rules proposals directed to a specific portion of the spectrum or to a specific service. They are also significant as a source of information to guide the Commission in its planning for International Radio Conferences, such as the one scheduled to be held at Geneva, Switzerland in 1959.

Some of you may wonder why I have discussed the legal and procedural technicalities of rule making to persons who are not lawyers. My reasons are simply these: All of you at some time or other are going to be concerned with modifications of existing Commission rules or proposals for new rules. In fact, I'm sure that most of you are now very much involved in current Commission rule making proceedings and legislative inquiries, such as those concerned with split channels, microwave allocations and allocations between 25 and 890 Mc. It is important to you to know some of the fundamentals of rule making if you are to insure that your viewpoint is made clear to the Commission and the merits of whatever you are advocating has an equitable opportunity to be granted. This is important not only from your own point of view as representatives of industry, but also from the Commission's standpoint. For the Commission wants and needs full information, so that it can properly fulfill its statutory duty to act in the public interest.

As I said before, in the field with which you are concerned, the basic arena for contest is not the licensing process but the rule making process. If you are a potential user who is not now allocated space but who hopes to be able to use or expand the use of radio, that will be made possible by rule changes or denied in a rule making process. For example, today, we have outstanding proposals with respect to the use to be made of the additional channels which will result from splitting certain of the channels in the vehicular radio field. This process undoubtedly will result in a rearrangement of the proportion of the pie amongst present and potential users. Some industries which have had in the past 1% of the useable channels in a particular portion of the spectrum may end up with 3% after the use of the split channels has been determined. Others who have 1% of the same spectrum may end up with 1/2%, and some people who have had none up until now may for the first time have a 1/2 or even 1 percent of the spectrum. Thus, whether you be a user, or a manufacturer hoping to expend your potential customer through increased eligibility to use vehicular radio, the Commission's rule making process is important, and effective participation in such process is probably a necessity.

Now what exactly do I mean by effective participation? How do you go about making the best case for your point of view? If I may be permitted to paraphrase a well known television performer: "All we want are the facts, nothing but the facts." It is all well and good to flood the Commission with statements as to the importance of this industry or that and to state very emphatically that you need frequencies, but it really isn't very helpful to the Commission or for your position unless the broad conclusions are backed up with solid factual information that explains why you need frequencies and how you are going to use them.

Let me give you an example. Assume that you are filing comments on behalf of taxicab companies in a certain city, who are seeking more frequencies. You

might file comments which recite how important taxicabs are, that the existing taxicab frequencies are horribly overcrowded and that four more frequencies are absolutely essential. I suggest that this type of comment is not enough for your purposes or the Commission's.

What should you file in such a situation? Some of the facts which would be helpful are; the complete facts concerning present frequency occupancy--including the number of stations operating, the number of calls made during an average day and a peak hour, and the number and extent of the delays that have been experienced; also, the facts as to how the new frequecies would be used, and information as to the rate of expansion, both past and projected, of the taxicab radio business in your city.

Now what I have said is merely a rough illustration. Moreover, I do not want to mislead you. I don't want to create the impression that if you make a full and persuasive presentation that it will be a guarantee of success. Unfortunately, that is not the case. For, as I indicated, you engineers have not yet devised a means of expanding the spectrum to the extent that it will accommodate all those who have legitimate needs. And, if you have made a good case for the taxicabs, your competitors for additional frequecies may have made out as good a case or even a better one.

But, if you do submit complete, factual comments, you will be sure that your case, whatever the Commission's decision may be, has been fully and carefully considered. You will be sure that your comments won't be tossed aside by someone saying "Oh, that's just his opinion.

Vehicular communications are going to be increasingly involved in important rule making proceedings before the Communications Commission. The need for such communications, as well as for other types, is constantly growing, and this will result in many difficult rule making problems with respect to allocations, eligibility, equipment and what have you. I can assure you that the Commission and its staff are going to do their best to decide those problems equitably and expeditiously.

You engineers can be of tremendous help to the Commission in this difficult task if you make available to it the benefits of your skill and your experience. And you have the best reason in the world for doing so--your own self interest.

Panel Discussion

VEHICULAR COMMUNICATIONS AND THE RADIO SPECTRUM

Moderator -- Commodore E. M. Webster

Panel -- Edward W. Allen, Jr., Federal Communications Commission
Mason S. Collett, Atlantic Refining Company
C. M. Jansky, Jr., Jansky & Bailey, Inc.
D. E. Noble, Motorola, Incorporated
Francis M. Ryan, American Telephone & Telegraph Company

E. M. WEBSTER: I consider it a high honor and a great pleasure to moderate this session, especially as the subject is one with which I have been associated for so many years. Not only are the five members of the panel personal friends of mine, but it has been my pleasure to work closely with each of them in the application of radio and electronics in the public interest. Accordingly, I hold each in high regard.

These gentlemen are eminently qualified in their respective fields. They have received recognition not only in this country but abroad and have intimate knowledge of the subject to be discussed. Last night during our reception period several remarked to me that they were looking forward with keen interest to this panel discussion because they expected to see some fireworks or a battle royal.

Well, it is no secret that several of these gentlemen are known to have strong opinions, and disagreements among them do exist. This is not unusual and, in fact, it is healthy to get these divergent views out in the open. As one who has known them many years, I can assure you that any differences of opinion are honest differences. They play their cards on top of the table, fight fair for their views, and have the courage of their convictions.

Now I hope that Curtis Plummer (Chief of the FCC Safety and Special Services Bureau) and Arthur Gladstone (Chief of the Domestic Radio Facilities Division, Common Carrier Bureau, FCC) are in the room. They are going to hear from our panel some very sage advice, some of which they have undoubtedly heard before. After listening to some of the divergent views, they may be confused. However, this is not unusual and, of course, will be helpful to them.

Having mentioned staff members of the FCC, I cannot help but put in a kind word for them. Of course, I may be prejudiced because of my long association with that agency. I, for one, have confidence that the FCC staff, after listening to all the evidence in the frequency problems surrounding all the radio services including the vehicular services, will objectively and conscientiously advise the Commissioners what they consider best to bring order out of chaos.

As a moderator, I have already taken up too much time. You are present not to hear me, but to hear the panel. I will now call upon each panel member to give a talk of about ten minutes. Then we shall proceed to a question-and-discussion period. In order to be absolutely fair and objective, I will call upon them in alphabetical order.

Our first speaker will be Edward W. Allen, Jr., Chief Engineer of the FCC. Incidentally, Mr. Allen is also a lawyer. He became an IRE Member in 1944 and the grade of Fellow was conferred upon him in 1953. Mr. Allen is a product of the University of Virginia and George Washington University. He has served on IRE committees, including Wave Propagation and Papers Review. As Chief Engineer of the FCC, he has supervision over radio frequency problems, which today, as you know, are probably the outstanding problems in radio and electronics. I introduce to you Mr. Allen.

EDWARD W. ALLEN, JR.: This afternoon I will outline briefly the objectives of federal regulation as applied to the land mobile services and pose questions as to how well these objectives are being met.

The expression "land mobile service" as used by the FCC is approximately equivalent to vehicular communication as used in this group and by the IRE in general. In applying the federal statute on communications regulation to the land mobile service, it seems that the federal authority has at least four tasks to perform. They are:

(1) To determine what amount of spectrum space should be allocated to the land mobile services.

(2) To decide who shall be eligible to use the space so allocated.

(3) To adopt rules and procedures, including equipment standards and operating requirements, designed to assure maximum feasible use of the available spectrum space with a minimum of interference to others.

(4) To keep these allocations, rules, and procedures reasonably in step with the state of the electronics art and responsive to the ever-changing requirements of national

security and the national economy as a whole.

You might add a few more objectives or rephrase somewhat the ones I have listed. But, in general, the objectives of federal regulation in this field are essentially unchanging. The changes and the problems occur in trying to carry out these objectives.

For example, economics cannot be ignored at the level of national decision. As an instance of this, if splitting channels in half had meant a tenfold increase in equipment costs, I am reasonably certain that the Commission never would have issued orders to proceed with it. On the other hand, if the costs of split-channel equipment are no more, or little more, than conventional equipment, then there is justification for the actions where frequencies are in short supply. But where is the dividing line in terms of costs? How much is a frequency worth? How much is a mobile system worth to its user?

Essentially, vehicular radio is used to increase the productivity or efficiency of the vehicles and personnel involved in the performance of some function. This is true whether we are dealing with public safety, travel safety, industrial operations, or fast delivery of hot pizza pie. This is particularly true in the case of safety, though the productivity gains may not be readily measurable in terms of dollars. They are nonetheless real when they supply better service for the same cost, or the same service at less cost.

How is the FCC meeting the objectives I have enumerated? Certainly no one who has followed our proposals and decisions of the past two years can say we have been sitting on our hands. True, there have been some demands which we have not been able to satisfy. However, I have even heard a few complaints about the rapid tempo of events.

With regard to spectrum allocation for the land mobile services, the bands presently allocated and in use lie between 25 mc and 500 mc. As in most matters of allocation, this is partly due to foresight but also, in greater part, to historical factors. And, in this latter regard, I feel that the land mobile services are particularly fortunate.

An examination of the requirements for mobile services and of the characteristics of systems and radio waves, as we know them today, leads us to the conclusion that a broad optimum for frequency allocation purposes lies in this region of the spectrum. This leads me to believe, at least until there are some substantial changes in the radio art, that the land mobile service should lie between these approximate limits. For persons who plan to use only a single base station, I visualize the lower range as being ideal for rural service, the middle range for suburban service, and the upper range for urban service. More complex systems using remotely-controlled base transmitters and receivers will, of course, not be subject to the same limitations. But these complexities lead to additional frequency requirements and spectrum usage. Within these limits, the Commission expects that space now allocated will be used to the fullest practical extent before consideration is given to taking space away from some other service.

Full advantage must be taken of technical improvements, sound operating practices, and good suballocation and frequency assignment procedures. Some of the current questions in these areas on which discussion would be helpful are: (1) block allocations vs. interspersed allocation for the land mobile services; (2) single-frequency simplex vs. two-frequency simplex operation from the standpoint of traffic handling capacity per unit of spectrum, and hence spectrum economy balanced against operational requirements of its licenses; and (3) single sideband vs. fm for mobile services.

COMMODORE WEBSTER: Thank you, Mr. Allen. Our next speaker will be Mason S. Collett of the Atlantic Refining Company.

Mr. Collett is Manager of Communications for his company. He has been associated with communications for at least thirty-five years. During the war years, he was a communication officer in the U. S. Signal Corps, serving both in the United States and in the Pacific area. Mr. Collett is past Regional Chairman of the National Petroleum Frequency Association and is currently Chairman of the American Petroleum Institute Central Committee on Radio Facilities. I give you Mr. Collett.

MASON S. COLLETT: I have been told that my job today is to represent the private users of vehicular communications. By so doing, I am to relate something of the problems, plans, and ideas of the people who today hold nearly a million authorizations in the land mobile field.

Obviously, no one man can be a self-styled expert in such a large and expanding field. However, he might become one through the process of knowing less and less about more and more, until he finally knows almost nothing about everything. Obviously, too, as a representative of the petroleum industry, I must of necessity be better acquainted with the petroleum use of radio than with any other industrial user. And this is true despite the opportunity which I have had during the past three years as chairman of American Petroleum Institute Central Committee on Radio Facilities. This post enabled me to associate closely with other industry committees, such as the Forest Industry Radio Committee, American Gas Association, National Committee on Utilities Radio, Association of Railroads, A.P.O., and a host of others.

Few people realize the wide scope of the safety of industrial uses of radio. Let me use my own company, the Atlantic Refining Company, one of the medium-sized oil companies, as an example. We have, of course, always used radio telegraph

on our tankers. Since the war we have added radio telephones, fathometers, radar and loran to the electronic equipment in our fleet. Our first use of radio on land was the early 1,700 kc radio in our geophysical work in connection with our constant search for oil. Since the war we have added radar, shoran and vhf-fm equipment to the list of facilities used for this purpose. In 1935, we installed one of the first 30 mc commercial vhf systems in Philadelphia as a common carrier coastal harbor system. This system is still in service today in a somewhat limited way, and it occupies a frequency in the 30 mc to 40 mc band.

Today we, together with other marine users, have petitioned the FCC in the name of the Joint Executive Committee for the Improvement and Development of the Philadelphia Port Area to allow us to set up a 150 mc vhf bridge-to-bridge marine communication system in the Delaware Bay and Delaware River area. The system would improve safety in this congested approach to the Port of Philadelphia. Our use of 40 mc vehicular equipment in the off-shore production of oil and in our pipeline activity is vital to the safety of our operations. We use 150 mc and 450 mc equipment in our refinery operations and plant-protection work. We employ citizens band equipment to dispatch our oil burner service and emergency oil delivery trucks. We use 960 mc and 1,860 mc microwave in point-to-point service for dispatching and operating our domestic pipelines. Overseas we use our own 40 mc and 150 mc equipment to furnish all of our own communication in Venezuela.

From this, it is easy to see how important privately owned, operated, and maintained radio equipment has become to the safety and economy of a typical petroleum operation. Those of you who represent other users could make an equally impressive showing for your own operations. Certainly all of us are convinced that we must, as private radio users, retain the rights to control the use of the radio frequencies assigned to us. Not only is this essential to protect our position, but it is the best way to insure that the engineering, operation, and maintenance of our systems satisfy the standards which we establish to solve our own critical requirements.

In preparation for this meeting, I read Commodore Webster's (then Commissioner Webster, today Chairman Webster) the CCC in one man actually -- paper given to this group in Chicago in October 1951. It was interesting to note the things which he stressed six years ago as essential to the efficient use of the radio spectrum, and to the orderly growth of the service which had at that time been under permanent FCC rule for only two years. His first emphasis was on system engineering. And his second on technical progress in equipment design. For the future, he dwelt in some length on the possibilities of 20 kc split channel, and on growth in the 450 mc band. Applications were then arriving at the rate of 150,000 annually. I think it's now somewhere in the order of 200,000. Today his predictions have become facts and necessities in the use of vehicular radio spectrum.

At this point, full credit should be given to all of you who have played such an essential part in the rapid development of the mobile radio spectrum during the past six years; to the engineers and IRE Members who have contributed to design progress; to the overworked staff of the FCC who maintained orderly progress in the face of chaotic demands; and to the user-coordinating groups who have promoted efficient exploitation of the limited resources available. All of these people deserve a vote of appreciation and confidence. Truthfully, it seems to me that seldom has a natural resource, and that's what I consider the spectrum to be, had such amazing acceptance as has the vehicular spectrum in the past six years. Even the diaper service, which Commodore Webster mentioned facetiously six years ago, has found a place in the radio spectrum in the citizens band.

Today, most of the private radio users recognize the fact that the presently available frequencies can continue to serve us well only if every possible regulatory and technical effort is made to improve the efficiency of our use of the radio spectrum. To this end, the petroleum users helped pioneer the testing of split channel equipment in the 40 mc to 50 mc band, and made the first formal application to the FCC for its use. We have only a month ago cooperated with the Forest Industries group on the first application of the principle of geographic sharing among user groups. In this instance, responsive to the Commission's proposal in Docket 12169 that these two groups share frequencies, we met in New Orleans and worked out an understanding as to how such frequencies will be coordinated. I think this is a step in the right direction and I'm certain it will be followed in other areas, especially in the metropolitan areas where the few hundred presently available channels are approaching saturation at the most rapid rate.

As to the future, we should be emphatic in our demand that a minimum block of frequencies be reserved on a nation-wide basis for future essential users in each user group wherever those users might appear. No one can predict, for example, where a pipeline may be built or where some industrial development may require radio for police and fire protection in some new community. The first step toward geographic sharing will probably evolve in a scheme whereby all unused frequencies in any given area, which are not reserved for users on a nation-wide basis, will be thrown into a pool to serve all eligible radio users on a first-come, first-serve basis. Eligibility in any such pool or broad-band system could never be determined with complete fairness and with priority to essential users. In my opinion, the pool idea needs a lot of consideration before it's carried to any great length. It seems obvious to us that those users whose services are most essential to the public safety and necessity should have priority over those services essential only to the public convenience. But who is to make this determination?

It is not easy to deny the use of radio to any business or industry which can use it to make a profit, or to reduce the cost of their services

to the public. This principle has already been established in the use of the citizens band. Today, in Philadelphia, for example, an amusement-machine service company operates on a citizen frequency adjacent to that used by our oil-burner service vehicles. This company is not at all loathe to complain about interference from our service. Certainly, no one in the user group would wish to deny the use of radio to any potential user if there is no problem of frequency availability. It seems to us that the complexity and cost of the administration of the vehicular radio service will increase about as a square of the number of users. It should be obvious that the FCC can cope with the job ahead only if the public is educated to recognize the rapidly growing importance of mobile radio and of the job that the Safety and Special Services Bureau has to do. Only then will Congress provide the funds required to cope with the job of regulation.

Despite the rapid expansion of vehicular communication in urban areas, we feel that in the remote and off-shore areas of this nation, and of its territories, some of the vehicular frequencies, particularly in the 450 mc band, could well be released for an economical point-to-point service utilizing the multichannel equipment which is now appearing on the market. To do otherwise, to our mind, is to be wasteful of natural resources. There exists a most definite need to provide a few relatively narrow-band, point-to-point channels in or near the 450 mc band. These would replace the 72 mc to 76 mc frequencies which have become almost worthless since the tv interference restrictions were placed upon them.

Finally, all informed private users of radio must recognize that in perhaps five to ten years, at the present rate of expansion, the presently available communications spectrum will be completely saturated in some areas despite all improvements in regulation and equipment. When this day comes, the pressure for new spectrum space will be irresistible. It is, of course, very easy to point a finger at any little-used part of the spectrum and say, "Take part of that." For example, it is hard for our people to understand why the Safety and Special Services must be so crowded when the uhf tv band is virtually unused. Here, let me digress for a moment to be sure that statement is not misunderstood. In one of our recent filings with the Commission, we made a forthright statement with respect to the international allocation of fm and uhf tv on a shared basis with mobile services. The statement was misinterpreted as being our effort to secure sharing with those services at the moment. This was not intended. Actually, in our opinion, allocation of frequencies is a prerogative of the Commission. We feel that it is our duty, and this we've always done, to make the very best showing of our needs and of the use we are making of the frequencies assigned to us. We would then expect the Commission to review our needs and use of frequencies as compared to the needs and uses of all others and from there allocate wisely and judiciously, and I'm sure they will.

It is wise to reserve some frequencies above 890 mc for urban vehicular use. But it would seem that the uhf bands should be fully utilized before mobile services are forced to move to microwave bands. Then, too, we wonder if it isn't time to take a look at the lower frequencies, even at those below 25 mc. Recently, for example, we heard of an American-made, single-sideband mobile unit operating with 30 watts in the 7 mc band talking over a distance of approximately 300 miles in Venezuela. Such long-range vehicular communications would be of obvious value in the remote and off-shore areas. In fact, a petroleum user has already been granted permission to use single-sideband equipment in the Gulf (operating, I think, in the 2 mc band).

Truthfully, I can make less claim of being a radio prophet than I can of being an electronic expert. My contribution to this panel today is to represent those who use and pay for the equipment that Dr. Noble and his colleagues develop and Mr. Allen and his people regulate. In short, I represent the demand. I hope that the others can be the supply when it comes to prognosticating the future.

COMMODORE WEBSTER: Thank you, Mr. Collett. Our next speaker will be C. M. Jansky, Jr., Chairman of the Board of Jansky & Bailey, Inc., Radio Consulting Engineers. He joined the IRE in 1918 and was honored with the grade of Fellow in 1928. He was President of the IRE in 1934, and over his many years as a member has been a director and member of many committees.

Mr. Jansky is a product of the University of Wisconsin. He also taught at the University, and there are many outstanding figures in the radio field who studied under him.

I really don't remember when I first met C. M., but it was a long time ago. It has been my pleasure to work with him in connection with many vehicular radio problems -- especially in the marine field. He is nationally and internationally known and respected. I am sure he will give you something constructive to carry home and think about. I take pleasure in presenting to you Mr. Jansky.

C. M. JANSKY: Commodore Webster referred to my having been a teacher. Quite a number of years ago (more than I like to admit) as a teacher of collegiate radio communication courses, I used to tell my students that every radio communications circuit consisted of three parts -- a radio transmitting installation, a radio receiving installation, and the radio transmission medium connecting the two. Since an essential part of any radio communications system is the radio transmission medium, we find ourselves concerned with the transmission characteristics of this medium and, therefore, with the radio spectrum and its use.

Usually a radio communications system intended to perform certain functions is composed of a plurality of radio circuits. In general, a radio communications system is a much more complex entity than a radio circuit. Therefore, if we are

going to discuss vehicular communication, and the efficient use of the radio spectrum, it is logical and essential that we consider the requirements for and the characteristics of the transmission medium.

Now, there are many types of vehicular radio systems. Some are intended to serve the specific needs of law enforcement agencies, while others are used for dispatching taxi cabs. Some are designed to interconnect those in moving automobiles with land telephone systems; some to meet the requirements of aircraft operations; and still others to meet the maritime safety and operational requirements of vessels both large and small. (I am assuming that a ship is a vehicle.) There are many types; many other types.

The capabilities of a radio communications system are circumscribed by the propagation characteristics of the radio frequencies used and the amount of spectrum space available, that is, the number of channels incorporated in the system. Assuming that the objective is a system taking advantage of the propagation characteristics of a number of channels in a given portion of the radio spectrum, the first step then is to obtain a clear understanding and a definition of basic operational requirements.

To illustrate, I will use the type of system with which I am most familiar, namely, the basic operational requirement for a short-range maritime safety navigational and operational radiotelephone system. There is allocated for such a system in Canada and the United States, and also in other parts of the world, a number of channels in the vicinity of 150 mc.

Among the first questions which should be asked is what the distant ranges are which can be obtained over radio circuits using these channels. Channels of 150 mc even with small amounts of power are not line of sight -- far from it. Using frequency modulation over water, reliable distant ranges of 30 miles to 40 miles are obtained, and at times (a larger number of times than some of us suspected) and under certain circumstances, the ranges obtained are much greater.

Experience has demonstrated that a 150 mc maritime radiotelephone system can easily meet practically all navigational and piloting communication requirements, a certain percentage of safety distress requirements, and a certain percentage of public correspondence radio circuit requirements.

Next, what functions will the system be called upon to perform? In other words, for what types of communication will the system be used, and what will be the probable traffic load? Here we are able to draw upon experience already gained in the use of radiotelephony on channels in other parts of the radio spectrum. Also, this experience can furnish the basis for establishing basic operational requirements and, next, operational specifications for the type of apparatus necessary to make the system work.

If you will forgive me, I shall again use the vhf-fm 150 mc maritime radiotelephone system as an illustration. Past experience with systems using channels in other parts of the spectrum, together with experimental work in this field, has shown that an adequate short-range universal vhf maritime system will be used for intercommunication between large vessels, between small vessels, between large and small vessels (such as yachts, fishing craft, and so forth). It will be used for communication between vessels and safety shore stations (e.g., United States Coast Guard stations); for intercommunication between vessels and locks, vessels and harbor guidance or control shore stations, tugs and their dispatch stations, vessels and bridges, and docks and piers; for intercommunication between vessels and public correspondence shore stations for entering the land telephone system, and for many other functions, some of which cannot be anticipated in advance of more experience with the system.

Now, the compilation of functions listed above is based upon experience. The inevitable conclusion is that in certain areas (or any area), if the system is any good, it will be used extensively. Therefore, a substantial amount of traffic must be handled. To handle this traffic, either some way must be found to handle in the same area a number of communication circuits simultaneously on the same channel, or there must be available a number of channels for simultaneous use. Since I don't see much hope of the first solution to this problem, a basic requirement is for a multichannel system.

This brings me to the third basic requirement for an adequate vhf maritime system, the technical and operational characteristics of the radio transmitting and receiving sets to be used in the system. Obviously a multichannel system requires multichannel equipment, possessing features called for by the manner in which the system is to operate.

Here I wish to direct attention to a philosophy of approach to the apparatus problem which seems to need some emphasis in the United States. The characteristics of a system should not be circumscribed or limited by what happens to be the limited capabilities of equipment which manufacturers happen to be producing or have on their shelves at a particular time. The specifications for the system should come first. Then the apparatus for the system should be designed to meet operational requirements.

I make the above statements with some feeling because here in the United States there is evidence that the full development of the maritime vhf system has been handicapped because, with some exceptions, United States manufacturers have shown little interest in developing and selling multichannel equipment of the right characteristics for sale at reasonable prices. This situation does not exist abroad. In the European countries where the necessity for the multichannel concept is more generally recognized than in the United States, there are quite a number of companies producing and selling multichannel vhf sets at prices which, comparatively speaking, are not too much higher than those charged for single-channel sets over

here. So, unless United States manufacturers recognize basic systems requirements and build apparatus to meet them, they must not be surprised if they lose valuable domestic markets to foreign manufacturers who have developed techniques for efficiently producing moderate-sized lots of equipment.

In summary, the efficient use of the radio spectrum for building a radio communications system possessing specific characteristics requires the following: first, a clear definition of operational requirements; second, the allocation of a sufficient number of radio channels for the system in the right portion of the radio spectrum; third, the adoption of the right operating rules for the use of those channels and fourth, the availability at reasonable prices of radio equipment which meets basic operational and technical requirements. These principles hold for the efficient use of the radio spectrum in the building of any vehicular radio communication system.

COMMODORE WEBSTER: Thank you, Mr. Jansky. Our next speaker will be Professor Dan Noble. All of you know him or have heard about him. Our time limitation prevents me from taking the next hour or two to tell you what he has done, what he is now doing, and what he wants to do. So -- just a broad-brush picture.

Professor Noble is Director and Executive Vice-President of Motorola, Incorporated, in charge of Industrial, Semiconductors and Military Electronics Division. He became an IRE Member in 1925 and was honored with the grade of Fellow in 1947. He has served on numerous committees of the Institute and was Chairman of the Connecticut Valley Section in 1938. Professor Noble is a product of the University of Connecticut, where he also taught.

The first time I met Dr. Noble was in the early 1930's. He was then assisting the State of Connecticut to develop and put into operation a state-wide police radiocommunication system, one of the first of its kind in the United States and a model for many police systems to follow. In those early days he was looking with a vision far beyond many of us in the vehicular radio field. He seized the opportunity and saw a job to be done. Accordingly, he abandoned the academic field and went into industry.

Professor Noble devotes twenty-four hours a day to radio and electronics -- and drives himself hard. When he gets a chance to eat and sleep, I don't know. He is devoted to constructive thinking and often his views are provocative, giving us something to think about. I need go no further. I present Professor Dan Noble.

D. E. NOBLE: You know, it's always dangerous to ask a professor, or even a former professor, to speak. Although it's easy to get us to start talking, it's hard to get us to stop. And professors can be very boring.

Spectrum utilization is a four-dimensional problem involving bandwidth, space, time, and eligibility. For the maximum utilization of the spectrum for mobile communications, we should make use of the minimum frequency band, the minimum space between stations, and the minimum time on the air for time-sharing among stations. And, to avoid saturation, we should utilize the minimum eligibility for users who must be selected by a priority system based upon the concept of public interest, convenience, and necessity, defined both in terms of benefit to the public and the national defense.

Frequency designation and bandwidths, which we might more clearly identify as channel assignments, may be determined by many factors. But in a practical case, the dominating influences are the modulation spectrum and the guard bands which are required to avoid interference from adjacent stations. We are concerned with direct interference, intermodulation, and receiver desensitizing effects.

The history of the development of the mobile art discloses substantial advances in the development of equipment which will limit interference intermodulation and desensitizing. Transmitter noise and splatter has been brought under close control. Receivers have been designed with remarkable intermediate frequency selectivity characteristics and with comparatively high tolerance for signals which would ordinarily produce disastrous intermodulation or receiver desensitizing. The art of frequency modulation equipment design is rapidly maturing, and significant advances are not in sight which will change the channel occupancy pattern substantially beyond that which can be achieved in the so-called split channel spectrum subdivision.

We can expect advances in equipment reliability and changes in power demands and dimensions resulting from the application of transistors and other solid-state devices. We can see the development of the needed black box, which will provide rf selectivity with the same bandpass characteristics which we now build into our IF filters. RF selectivity improvement is the most needed advance to revolutionize spectrum occupancy, and while crystal filters and quarter-wave line sections help in specific interference situations, the selectivity provided by such devices are whole orders of magnitude away from the selectivity we really need.

I have been talking only about frequency modulation. I believe that an exploration of other forms of modulation leads us naturally to the single-sideband system. Ultimately, the modulation spectrum for single sideband can be limited to about 3 kc for voice communication. We would expect, with the advance in the art, to find it possible to place radio communication channels in operation every 4 kc to 6 kc across the mobile spectrum. While the use of single-sideband techniques does not eliminate intermodulation and desensitizing, it does provide a whole new set of dimensions in relation to such problems.

On the basis of field experience, I cannot predict at this time what the ultimate potential is for single-sideband-system channel spacing for

acceptable voice communication. I do feel, however, that the ultimate use of single-sideband communication does have a potential for a substantial increase in spectrum loading within the limits of destructive interference. The exploitation of modern techniques of computer technology, control, and interlock can even provide for multiple station coordination in a given area without the need for centralizing all stations in a single group configuration. While I certainly do not advocate an immediate move to single-sideband modulation, I do feel that we must constantly test the potential of such a system for a posssible improvement in spectrum utilization.

In the past, because it has been simpler for the FCC to administer allocations in this way, block service-channel assignments on a horizontal assignment basis stretched the assignment uniformly across the boundaries of our country. Decatur, Illinois, has the same number of police channels available as New York City or Boston. Bisbee, Arizona, has the same number of railroad channels as Chicago, Illinois. The space concept of assignments has been used in large metropolitan areas to permit the duplicate assignment of channels outside a calculated area of interference. Repetition of channel assignments within the service category is common practice. But distribution of channel assignments on the geographical basis, independent of service categories, has been avoided because of the administration problems inherent in the licensing processing under such a system.

So long as the spectrum was not approaching saturation, the avoidance of geographical allocations was logical and understandable. But as we approach saturation in the utilization of the spectrum, the horizontal allocation to categories can no longer be tolerated, and some scientifically objective plan must be formulated to permit the efficient administration of geographical assignments. The ultimate pattern will make use of a grid plan, disciplined by a properly integrated computer control. In the final resolution of such an approach, the proper encoding of fundamental information on a card will cause the computer to serve up the definitive information assignment information for licensing a given applicant in a particular geographical area.

No matter what we do from a technological point of view, we shall probably approach saturation of spectrum utilization in the vhf and uhf portions of the spectrum. Time sharing and eligibility must be resorted to for the maximum use of these vital spectrum areas for the greatest public good. Channel time sharing is one possible means of extending deficiency of channel occupancy. Such time sharing can be developed both by the use of interlock control systems, that is, disciplining the use of a single station by several users, or by the use of a carrier-controlled interlock which would provide time sharing among several independent stations on the same channel but with geographical seperation of the base stations. Ullimited eligibility for the use of uhf and vhf mobile channels would invite allocation saturation. In considering spectrum-utilization efficiency, we must take into account the value, or the importance, of the communications accomplished as well as a quantity of communications. Spectrum scarcity must go hand-in-hand with eligibility disciplines to limit the use of the spectrum to those services which qualify at the top of any public-interest, convenience and necessity evaluation. And we must always think in terms of the importance of mobile systems to national and civilian defense. The radio spectrum is a limited national resource. Undisciplined and indiscriminate use of the spectrum by the general public should be avoided unless it can be shown that there is spectrum space in excess of that needed to satisfy all of the requirements of top-priority services.

I think it is clear to all of us that the present allocation pattern is obsolete in terms of potential efficient utilization based upon a configuration which mught be developed with complete scientific objectivity. The FCC and IRAC administer with duplicate and divided authority over spectrum assignments. Only the voluntary coordination of the two groups has prevented the chaos of complete assignment duplications. Years ago, when the original spectrum division was made between the FCC and IRAC, the pattern was based upon the arbitrary division of blocks of spectrum to governmental and nongovernmental use. I think it was hoped, with the limited knowledge of propagation at that time, that this block sampling of the entire spectrum would provide usable bands, no matter what turn might be taken in the development of the radio art. Everyone concerned has made the best use of this chopped-up, limited block discontinuity of spectrum division. As a first approach to the problem, the pattern was probably justified.

Today, with the present state of the art, a spectrum study and a re-evaluation of allocations for both governmental and nongovernmental spectrum portions are overdue. I do not think that we can assume that the military and governmental assignments are excessive. However, I think it is fair to assume that they may not be the most intelligent for meeting national defense requirements. And we certainly know that the nongovernmental assignments are less than intelligent when viewed objectively.

It is important to all of us that adequate channels be assigned for vital military electronic applications. It is also important that our assignments for mass communications and for land-mobile, air-mobile, and water-mobile communications systems be adequate and effective. It is my hope that an engineering study, free from partisanship and politics, would point the way toward more effective utilization to make possible, through the adequate disciplining of the four dimensions of assignment, an over-all gain for all users of the spectrum without the loss of any of the user categories. I do not question the need for adequate assignment of frequencies for general governmental use, but I have always questioned the validity of the IRAC distribution approach.

Efficient spectrum utilization can be approached through the discipline of scientific objectivity. Much of the engineering capability rests with industry, and it is doubtful that the military is aware of the inadequacies of its frequency utilization pattern. I should like to see a spectrum study developed with mutual confidence between the governmental and nongovernmental groups, and with the general expectation that no one will lose and everybody will gain as the result of an intelligent evaluation of spectrum utiliztion.

As you know, the Electronic Industries Association has voted to investigate the possible implementation of spectrum exploration. It is not intended to carry on such an exploration within the pattern of EIA membership, but rather to join with other interested parties to examine the spectrum with the objective of improving total utilization by the government, military, and nongovernment alike. My personal feeling is that the ultimate exploration must be carried on under the jurisdiction of Congress and with authority assigned by a suitable Congressional act or resolution. Industry's role would be one of contrib uting the necessary engineering talent. I might point out that industry's dollar stake in such a program would amount to many hundreds of thousands of dollars, and the job would be accepted only because industry is convinced that the accomplishment of this task is essential to its future health and to the national health.

I believe it is also true that most of the people concerned with this spectrum study visualize it as a fact-finding investigation, followed by an evolution to a constantly improving pattern of allocations, frequency assignments, and licensing. A revolution would result in chaos, and changes in spectrum assignment must be accomplished with ample time to adjust capital investments and to realign equipment standards in design. Five, ten, fifteen, and twenty year programs should be evolved, and constant reviews should adjust spectrum utilization to keep pace with the development of the art.

Once we have evolved the study, we should make sure that the development of another straight-jacket which can limit and degrade the potential spectrum contributions is avoided. The future of mobile communications is bound up with this spectrum study, and adequate mobile communications can be achieved only when all four dimensions of spectrum utilization are fully rationalized in terms of the importance of the mobile services to all of the people of the United States.

COMMODORE WEBSTER: Our last speaker is Francis Ryan. He is a radio engineer with the American Telephone and Telegraph Company and, I am sure, is well known to all of you. Mr. Ryan has been a member of IRE for forty-three years and has been active in many committees. He became a Fellow of the Institute in 1940. Last year, he was Chairman of the Professional Group on Communications Systems.

Mr. Ryan comes out of the West, the University of Washington. He has had long association with the radio art, starting as a radio operator on a merchant ship, and has contributed much to the whole field of mobile radio, aeronautical, marine, and land-mobile. Backed by such a long history and experience, his presentation will undoubtedly be interesting and worthwhile.

FRANCIS M. RYAN: When people are on the move, they have about the same need for communication as they do when they are in fixed locations, perhaps even a little more need in some cases. Now, our country is certainly one where people are becoming more mobile. They are on the move more and more in the air, on land, and at sea, and this is developing a very great demand for mobile communication. For the general public, that need can be met only by a public mobile telephone service. And my discussion this afternoon will be limited to such service, that is, public mobile telephone service as given by the telephone companies.

The Bell Companies desire to give good service and to do as good a job in giving mobile telephone service as is generally done in giving telephone service between fixed locations. (I think the independents would have exactly the same view.) We might pause to consider what progress has been made toward that objective, particularly with respect to the service for land vehicles.

The Bell Companies have established mobile telephone service in nearly 300 locations in the United States. To be exact, I think there are 293 locations. At these locations there are in service 485 base station channels, serving more than 17,000 land vehicles.

While substantial progress has been made in developing public mobile telephone service, we are a long way from our goal of providing the quantity and quality that the public is entitled to and which it is possible to develop. We believe that a bold new approach to this matter is necessary on the part of all concerned. So far, we have been able to serve only a small fraction of the people who really need mobile telephone service.

We are certain that the quantity of service that the public needs cannot be provided simply by the addition of single channel facilities, such as are presently installed. We believe that the next step is the development of a multichannel system suitable for simultaneously serving large numbers of mobile units in metropolitan areas. With the channels presently allocated for public service, only about 14 mobile circuits can be set up in a city. As a matter of fact, if the adjacent communities have service, the number of circuits that can be provided in a city is even less. Now, this means that only about 1,000 and 1,200 mobile units can be served in a metropolitan area. And even 1,000 units are possible only with 70 mobile units on each channel. This is certainly a party line

with a vengance. How few these 1,000 or 1,200 units are for a large metropolitan area is apparent when you realize that Los Angeles alone has some 2,500,000 motor vehicles operating within its limits.

I'd like to consider with you for a moment in terms of the principal service categories the present frequency allocations in the 25 mc to 890 mc range. Almost 60 per cent of the frequency space is devoted to broadcasting in one form or another, fm and tv. A little more than 25 per cent cent is devoted to government services. I think amateurs have perhaps 4 per cent, maybe a bit more. The Aeronautical Service and the Safety and Special Services have only about 3 per cent, and the Citizens Service has maybe 1 per cent. Then you find that the Common Carrier Service has less than one half of 1 per cent, certainly the low man on the totem pole.

These allocations for the Common Carrier Service are not just for telephone companies. They include those for miscellaneous and other common carriers. When you consider that an allocation for common carrier service is in itself setting aside frequencies for the use of all of the people, many of whom can turn only here for service, you see how really meager these allocations are. They have been so meager that it has not been possible to develop in any substantial way the potentialities of mobile telephone service.

If we are to have expanded mobile telephone service, the first step must be the allocation of additional frequencies. If adequate allocations are made, the Bell System will proceed to develop a broad-band multichannel system suitable for serving large numbers of mobile customers in metropolitan areas. What capacity should that system have for this initial step forward? I think it should first be large enough to be economically feasible. Secondly, it should be large enough to permit using methods that will give effective frequency utilization. Finally, it should be large enough so that it will provide for a large metropolitan area a reasonable period ahead. It is our view that 200 channels represents the minimum that meets these criteria.

Where in the spectrum should these allocations be? They should be high enough so that one is not plagued with long-range interference, and low enough so that the frequencies have good short-range propagation characteristics. We believe that the frequency range between about 60 mc and 500 mc best meets these requirements. Frequencies above 500 mc have the disadvantage of requiring substantially increased power. For example, if one were to try to provide a thirty-mile service radius at 1,000 mc, something like four times as much power would be required as at 500 mc.

What bandwidth and how much spectrum would need to be allocated for this step in the development of public mobile telephone service, that is, for the establishment of 200 channels or a system with a capacity of 200 channels? Or course, it varies somewhat, depending on the position in the spectrum. For example, about 14 mc would suffice at about 100 mc, and it would take about 20 mc at 400 mc.

In the Bell System, we hope that the present inquiry into frequency allocations that the FCC has undertaken in the 25 mc to 890 mc range will lead to the allocation of the added frequencies necessary to go ahead with this step. The Bell System has currently before the Commission a petition asking for the allocation of sufficient frequency space in the 60 mc to 500 mc range for the development of a 200 channel system.

The public, more and more mobile, is entitled to greater and better mobile telephone service. A large technical development has to be carried out to create the kind of system I am talking about. If the allocations are made, this program of development can proceed.

COMMODORE WEBSTER: Thank you, Mr. Ryan. We have now arrived at the question and answer period. I believe it would help if I conducted a warm-up before throwing the questioning to the assembly.

Mr. Allen, I'm asking you this question because to me rf allocation problems originate at the international level. I've attended all the international conferences, beginning in 1925. It seems that our whole spectrum -- its breakdown and everything we do in it -- stems from what they agree upon at those meetings. This doesn't mean all the details but the framework there upon which the spectrum is built. What will the International Radio Conference in 1959 mean to the Land Mobile Service?

MR. ALLEN: I can give you a reply, but I'm not sure I can give you an answer. Whatever I say that's at all definite will probably put me out on a limb to a certain extent. As you've said, there's an allocation proceeding underway between the 25 mc and 890 mc range at the Commission. The land mobile services are vitally concerned with this proceeding since their allocations lie in this band. However, this is in the nature of a legislative inquiry. It is neither an adjudicatory proceeding nor a specific rule-making proposal. We have no proposals out for allocation changes in that inquiry. It's designed to give the Commission information as to what other users, or prospective users of spectrum space within this area, there are who have not heretofore made their wants known to us by specific petitions or inquiries. So far as I know, the Commission and the staff have no definite changes in mind. I don't know what's going to come out of the examination of the replies to that inquiry. But whatever proposals are made, the public will have full notice as to what they will be, since we have to go through a rule-making proceeding in order to effect such a change. As I say, I don't know of any changes at present that will be involved except, perhaps, in certain minor categories.

COMMODORE WEBSTER: Thanks, Ed. Now, for Mr. Collett. It is understood that private mobile facilities, such as those in the petroleum service, are sometimes used for communication with aircraft as with land vehicles. Has this use been extensive, and how long as long-range interference been experienced?

MR. COLLETT: In the petroleum service, such a technique has been used. I'm not certain about other services. I wouldn't say that the use has been extensive. Generally, you would find it in pipeline patrol planes or, possibly, in personnel- and equipment-carrying planes. In the former, the altitude at which the planes fly is not great -- sometimes not as great as the elevation of antennas (which have been knocked down on occasion). In the other case, the hops are rather short, and the elevation of the planes is, therefore, not great. To my knowledge, there's been no problem of long-range interference, which is probably no greater than we get from normal skip interference.

COMMODORE WEBSTER: Thank you. Mr. Jansky, in regard to some of the problems you spoke of in your paper, how would you suggest we sell ocean shipping on the idea of using vhf radio?

MR. JANSKY: As I pointed out in opening remarks, we have a multichannel vhf allocation in the 150 mc band, having a number of channels. It appears at this moment that this system is capable of handling a great deal of traffic. We have for the use of these channels a set of operating rules, which the Commission adopted after extended hearings and discussions. In certain areas on this side of the ocean and elsewhere, there has been a good deal of experience in the use of this system. to meet the navigational and operational and, to the extent possible, the public correspondent's requirements of shipping. And, it seems that the results have been generally satisfactory. There is also considerable experience being gained with a system very similar, in fact almost identical, in Europe. Once having settled the argument with our European friends as to whether we were going to use fm or AM in this band (our European friends decding they would go along with fm), I predicted that European nations were going to pick up the ball and carry it. They have been doing this.

If there's any part of the maritime industry or any group concerned with the operation of vessels large and small that is interested in seeing the workings of this system which is now provided by an allocation structure and operating rule, there are many opportunities to study it at first hand both here and abroad. To those who feel that navigational vhf communication might have uses in some areas where it hasn't been employed, I recommend a study of the use that has already been made of the systems here and abroad. I think such a study would do the selling.

COMMODORE WEBSTER: Thank you. Dr. Noble, assuming comparative factory runs, what would be the comparative selling price of a 15 watt mobile unit at 150 mc, 450 mc, and 960 mc? And when will a fully transistorized portable and mobile unit be available on the 40 mc and 150 mc band?

DR. NOBLE: These extensions of the art to new equipment always involve a temporary increase in cost. (I think the history has shown that the increase is temporary.) Our initial equipment was in the 30 mc to 40 mc band; then we went up to 150 mc. This was a little more expensive to begin with, but the difference in cost eventually disappeared. Going up to 450 mc involves some increase in cost, but this is not going to be permanent. In the ascent from 450 mc to 960 mc, which are pretty closely allied, there's a slight increase, maybe ten to fifteen per cent. But this is neither a tremendous extension of the art nor a big risk in cost. Awaiting us is the application of transistors and solid-state devices, which will accomplish a great deal in these upper regions. There are some magnificent devices in the laboratory that will do wonders in 450 mc and 960 mc and even in higher frequencies. They will do more than tubes. As the art in the solid-state electronic area progresses, the effectiveness of equipment design in this upper range of the spectrum is going to improve quite markedly.

I've also been asked when will a fully transistorized portable mobile unit be available in 40 mc to 150 mc. First of all, from the phrasing of this question, transmitters and receivers must be considered. I don't visualize any 30 watt transmitters with solid-state devices in the near future. However, I can see 1 watt transmitters with solid-state amplifiers. There exist in the laboratory transistors with 1 watt output up to about 200 mc or 300 mc. A fully transistorized portable transmitter and receiver will be available eventually. But the unit will not appear rapidly because the special devices in the laboratories are very costly, and it will be some time before it's available at a reasonable cost.

I have to enlarge a bit here because I think it's obvious to almost everybody that transistors haven't been thrown into the present mobile units primarily because the ambient temperature of the present design of germanium transistors usually shouldn't exceed something of the order of 60°C. Although they will work under certain specific designs up to 100°C, 60°C is a nominal limit, and our tubes in the equipment create too high a temperature. The individual furnaces in each tube make it unpleasant for the transistors. Of course, silicon transistors are in the offing. They will come along and make possible such close association, tube to transistor, without concern about temperature. But silicon transistors are still costly and difficult to manufacture, and in general they are not as good for the really high end of the spectrum as are the germanium units.

Thus, the mobile receiver units must wait for a specific transistor design which will take care of the temperature problem. In the mobile units the transmitters are going to wait a long time. I don't see in the art any high-power transistors that will take care of the present mobile power

ratings. I believe that over the next two years we will find transistors on the market in the high frequency region that will take care of the first and second IF and rf end of the receiver and thus enable us to release completely transistorized receivers. There are such transistors in the laboratory and, to a limited extent, on the market. But the full range of transistors for the rf and even for the high IF frequencies are not available in adequate quantities and, most particularly, at moderate prices, to make it practicable to move them into the equipment. The temperature factor is still the most limiting one, and this calls for a redesign. It does not mean you can just throw the transistors into the present package.

COMMODORE WEBSTER: Thank you, Dr. Noble. Now, Mr. Ryan, I've got two parts to this next question. Assuming that the common-carrier philosophy of the broad-band operation which you talked about is correct, to what use would the common carrier put these broad bands in rural and remote areas? Secondly, what system of priorities would you use in urban areas to determine who would be served under the system? Who would decide the merits of each case?

MR. RYAN: A substantial part of the band assigned or allocated to multichannel public telephone service should be available throughout the country for migratory vehicles, so that a vehicle can still get service even when it's some distance from home base. It would not be necessary, however, to have the whole band available in that way. In many portions of the country, particularly rural areas, part of the band could be used for other services. One use that could be made of the available channel space would be for point-to-point service. The Commission's present rules allow the mobile frequencies allocated for telephone company use to be used for point-to-point service secondarily, subject to noninterference with mobile service.

In the Bell Companies we do make a substantial use of these frequencies for such service. I think there are about 50 systems in the country, some of which provide only one telephone circuit; others, two; and some, five or six. They service remote areas, ranches, and the like, and are licensed in the Rural Telephone Service under part 21 of the Rules. In the case of the broad-band system, a similar use on a larger scale would be made. Perhaps the independent telephone companies would make more use of these frequencies than the Bell Companies. This is because, in general, the independents have a larger share of the rural areas, where there would be the need for point-to-point facilities and where the frequencies would not all be required for mobile service. I hasten to say that it would not be out of the question for some portion of the band allocated for use in the metropolitan areas for public mobile service to be used for some entirely different service in some parts of the country. I wouldn't want to try to point at any particular service. I think that the inquiry that the Commission is having should develop the possibilities of this kind of sharing.

The other question had to do with the priorities that would be necessary in the urban area. I take it that the questioner had in mind the possibility that the capacity of the entire multichannel system might be exhausted in this area. First, I hope that this will not be approached with the scarcity view. That doesn't mean, in any sense, that I think we should approach it with the idea of using the frequencies in an inefficient manner. We should develop as many channels as we practically can and make them available to everybody who needs them. And I hope we will be able to serve everyone who wants and needs the service.

You may call this wishful thinking and ask whether I've heard of the shortage in spectrum space. In reply, I might state that I belong to the same camp as Mr. Baker, who expressed some views on this at noon. Like Mr. Baker, I've been impressed by what engineers have been able to do to stretch the capacity of the spectrum.

No -- I'm not indulging in just wishful thinking. If we go ahead and do a 200 channel job and then find it isn't going to be enough, we can resort to some of the things you have to do to use frequencies less well-suited to mobile services. For example, that some of the microwave ranges might not be used with a very large number of low-power base stations isn't inconceivable. It would take an intricate network and, at the moment, appears economically impractical. But if we can get the thing going in a big enough way, then such a step will not appear so frightening. And, I hope it will not be necessary to have any priorities. However, the Commission does have a system of them now. I think it's a reasonable one, and I'm not able to suggest a better one.

COMMODORE WEBSTER: Thank you, Mr. Ryan. Now, gentlemen, I'd like you to ask whatever questions you have in mind. First question?

Question: My name is Ornstein. I'd like to ask Mr. Jansky whether there is any likelihood of a conflict between the needs of the vhf Maritime Service and those of the Land Mobile Service. I ask this especially in view of the fact that a fairly large number of channels have been allocated in other countries, particularly in the Hague agreement. Some of these channels are in use in this country for the Land Mobile Service. Also, might not a serious conflict arise as the vhf Marine Service develops?

MR. JANSKY: I'll give my personal opinion on that. It's true that the Hague agreement assigns more spectrum space to the Maritime Service than we do. There are other differences between the two allocation structures. One difference is that over there they lean very heavily on ship-shore navigational and public correspondent's circuits to two-frequency circuits. Now, all of our navigational ship-shore -- and I use the term "navigational" to include communication with locks, shore points, and the Coast Guard -- are single-frequency circuit. So, when you add up the number of channels, while it is true that they have more channels than we have, they don't have that many more. This is indicated by the excess of spectrum space they have.

It's also true there's a very nice overlap between the two allocation structures. On the basis of that overlap, a good deal of thinking and planning has been going forward towards something which we know we will have and which is much needed, that is, a world-wide international vhf system. It's my own personal opinion, and I hope these words don't rise up sometime to bite me, that using fm and with the amount of spectrum space and the number of channels assigned to the vhf-fm Maritime Service in the United States, the traffic handling capabilities of this system are tremendous if it is used right. In my opinion, the spectrum space allocated is adequate. So I don't think the solution of our problem is channel splitting to anything more than 50 kc separation between channels, but, rather, the preservation of fm and efficient systems engineering in the use of those channels.

COMMODORE WEBSTER: Would you mind, C. M., if I added something for the benefit of those who may not know what the Hague agreement is? It is an agreement among the Baltic and North Sea countries in regard to the use of vhf on boats in that area. The United States was an observer at the conference, and Mr. Jansky was present. We are not a party to this agreement. I just wanted to make that clear. While it is an area problem, it has international implications. I understand we were very helpful and gave them a great deal of information.

MR. JANSKY (?): Pardon me, Commodore. The United States delegation to the Hague was not an observer delegation. It was a working delegation, and the United States' representatives participated in the work of the conference to the fullest extent, just as other working delegations did. The United States did not sign the agreement, because its delegation did not have plenipotentiary power.

COMMODORE WEBSTER: Well, my phrasing was a little unfortunate. I meant to imply that we were not a party to it through the medium of a treaty. But we certainly did a great deal of work and a great deal to help them in reaching their solution. And I think they've probably helped us a lot, too. Now, has someone else a question?

Question: My name is Reutter. I would like to a ask Dr. Noble how he would envision an area frequency allocation plan which would be compatible with the needs of the many services which have vehicles operating throughout a major portion of the entire country.

DR. NOBLE: I would say only that that would be part of the total plan. I'm not enough of an expert to sit here and solve the geographical allocations pattern. But I do feel that a geographical approach will yield some increase in spectrum utilization. I certainly have not worked out the details of it. The special case you speak of, where some service is using the spectrum over the entire United States, would definitely be a part of the total plan, and provisions would be made for such special requirements.

Question: I am Jack Neubauer, and I have a question for Mr. Allen. There is a conflict in the suggested upper limit of mobile frequency, that is, over 890 mc, as related to the lower limit of point-to-point services. Would you discuss the Commission's approach to the reassignment of frequencies in this region?

MR. ALLEN: Are you referring to the fact that the two proceedings going on break at 890 mc and that both mobile and fixed occur on both sides of that break? Is that the problem?

Question (Mr. Neubauer): In the region of this break, we are considering that there is potentially a new mobile frequency useful spectrum area. It is not definitely assigned, however, and doesn't exist as such. In other words, what would be the Commission's philosophy in determining whether we should push it further down below 890 mc, where it might conflict with existing services, or above 890 mc, where it would conflict with the common-carrier point-to-point services?

MR. ALLEN: I see what you're driving at. And a part of the problem is the separation of these two legislative proceedings into the coverage of frequency bands above 890 mc and those below 890 mc. In general, the services separated above 890 mc fell into the microwave category, and the services below fell into other categories. However, in the Commission's mind and in the studies the staff will give to these, so far as I can see, there will be no division. These will be considered as separate and discrete categories. For example, if information comes in at one legislative proceeding indicating that the proper place for a service is below 890 mc, due consideration will be given to this. Such aspects would appear in any specific rule-making proposals which would come out as a result of the hearing. We don't put certain thoughts into certain cubicles and other thoughts into other cubicles.

COMMODORE WEBSTER: Mr. Collett referred in his talk a little while ago to something that relates to a question that was handed to me just as we were coming up here on the platform. Now, our panel was not forewarned on this at all. Apparently, we have a spy, or a traitor, in the room. Maybe I'll soften that and simply say that maybe there's someone here scouting this meeting, using the terminology of football and baseball. I don't dare reveal who it is because he has probably slipped out anyway. It's a rather provocative question, and I doubt if we're going to get anyone to agree to reply. It is in the nature of a continuation of Mr. Collett's remarks.

My reference to a spy and traitor is, of course, facetious, but here's the question. What designs, if any, have the mobile radio users, manufacturers, consultants, common carriers, and the regulatory agencies have upon frequencies now assigned to broadcasting? FM and tv in particular.

Now, I simply have given you the question that was given to me. As I say, I think somebody was scouting us, and he would have preferred not

to have gotten up and asked this himself, because I don't know what you would have done to him. Mr. Collett did give his opinion. I'm just wondering whether anyone else would like to make a statement. I'm not asking anyone in particular, but I'm leaving the door open for anyone who would like to say something on that subject.

(Unidentified Voice): No comment.

DR. NOBLE: I'll make a comment.

COMMODORE WEBSTER: All right, Dr. Noble.

DR. NOBLE: I'm brave. I think it's perfectly obvious to everybody that the broadcast industry is not using all the channel. Now, over a period of time, those channel must be used. And the mobile communications users are short of channels. So it's quite obvious to any reasonable person that the channels that aren't in use are going to be re-allocated to somebody. Certainly, we in the mobile field want our portion of the spectrum that's going to be re-allocated when it's re-allocated.

COMMODORE WEBSTER: Any of the rest of you? It's past the 4:30 mark set by the program, but I have at least one question. In fact, I have a whole group of questions here that have been handed to me me by various persons, and I'm prepared to stay asking questions for some hours. But I don't want to impose on you. But there are one or two, at least one, I might use as we close this meeting. I would like to go down the line of the panel.

The application of radio as a useful tool to mobile units on land has increased greatly during the last ten years. This was brought about by the concentrated development of radio equipment using the upper reaches of the radio spectrum. And this toll has become an important economic factor for the users. My guess is that there are today a million transmitter units licensed in the Land Mobile Service. What stage of the growth cycle do you think the Land Mobile Service is in?

MR. RYAN: I think it's in a comparatively early stage yet.

MR. COLLETT: I would say it's in the infancy to teen-age stage. This morning, Curtis Plummer's charts showed that we're still in the explosive-growth period. When do we stop growing? I don't know. But, in petroleum, we would predict that our requirements in the next five to ten years will be somewhere between three to five times what we now have.

DR. NOBLE: I also agree that it's far from the peak. It's clear, however, that the saturation in the availability of channel space for systems will cause a leveling off. We'll approach a steady state asymptotically after a time, if we don't get more spectrum space, or find new ways of stretching the utilization of space available.

MR. ALLEN: I agree that the Land Mobile Service has by no means reached its maturity or full growth. Although, looking at it as a whole, I think you have to distinguish between various services. Some of these have had a long period of growth and might not be expected to grow a great deal more; whereas others are either in their infancy or have not yet been provided for. If they are made eligible, there will certainly be a very large growth in some. All in all, I think there will be a much greater growth than we have had heretofore.

MR. JANSKY: With respect to both the Land Mobile Service and the Maritime Service, I think there undoubtedly is going to be a great deal of growth. But there's an implication in this which I'd like to comment on, prompted partly by that question from an unnamed source.

There are those who seem to conclude: "There's going to be tremendous growth; therefore, there must be more channels." I suggest we ask ourselves this question. Are we vulnerable to the charge that in this whole field we haven't done enough soul searching in order to be sure we're making the most efficient use of the channels we now have? Or that we can't do it better?

COMMODORE WEBSTER: Thank you, gentlemen. We're running over a bit, but I'm going to permit one more question from the floor and then ask one myself.

Question: My name is Charlie Ruddy, and I address my question to Mr. Allen. Some years ago on the Congressional, there was a telephone installation which may still be running. But isn't it significant that something must be holding up the art if we go along for years without common ordinary communications in our large vehicles -- trains, planes, and the like?

MR. RYAN: There has been much pioneering work done. In 1928 we worked on air-to-ground communication for civil aircraft. Of course, this sort of thing was done for military aircraft in World War I. But we still don't have an air-to-ground public service. The Commission has been good enough to let us make the experiment now underway in the Chicago-Detroit area, using some frequencies allocated to land mobile service. This experiment is indicating the need that such communication fills and the practicability of such service. But, unless frequency allocations are made for public aeronautical service, it just can't be developed. So far, it has had to share with ship service, and this has been entirely inadequate.

Previous FCC hearings found there were not enough frequencies available in the vhf range to provide for aeronautical service. It was suggested that microwave frequencies be used, specifically in the 3,500 to 3,700 range. This band of frequencies has been considered time and again, but it just is not suitable for air-ground telephony. The real reason we don't have a public air-to-ground service of an adequate sort is the lack of suitable frequency allocations.

A small start has been made in equipping a few trains, using the regular public land mobile channels that are serving vehicles.. There are many unsatisfactory things about this. For example, a train comes through an area and has a lot of calls which tie up the channel and prevent the people depending upon this channel from getting the service they need. It's been a sort of stop-gap arrangement. Again, the service has not been able to develop because of the lack of adequate allocations. If multichannel facilities, such as I've been talking about, were developed, I'm confident one of the things that would come about would be improved train service.

I certainly think any country that can afford to use as much of the spectrum as we do for entertainment purposes can find a way to make the added allocations necessary for improved and expanded two-way communication.

COMMODORE WEBSTER: My question is addressed to the whole panel. I would like it to be answered in the light of the limitations of the radio spectrum, the rapidly increasing use of the spectrum for vehicular radio service, and the recognition that progress in the radio art must be looked to for the solution of many problems. Now, the question. Do you believe that the FCC is proceeding a at too fast a pace towards constant pressure by including more and more rigid rules requirements aimed at forcing development of vehicular equipment for use of narrower and narrower channels? Are these rules and this pressure unreal?

MR. RYAN: I think the FCC is doing a very fine job job. I have the utmost respect for what they have done and the fairness with which they have approached their task. If I had any criticism at all on what's been done in the mobile field, I think it would be simply this. Through circumstances probably entirely out of their control they often have had to do the expedient thing to meet some immediate situation and have not had a chance to do the necessary long-range planning and the things that will basically insure the right answers in the future. This is not really criticism, because I find in my own work the same problem. We all have it; everyday we have to do something about the things that are "right on our necks." But somehow we must find time to look further ahead. I believe that these two proceedings the FCC has instituted (allocation proceedings 25 mc to 890 mc and above 890 mc) are exactly what is needed, and I think the Commission deserves a great amount of credit for what it's doing.

MR. COLLETT: I think the immense activity in this direction is actually long overdue. The only question I have is whether the Commission is adequately staffed to deal with the volume of new rule-making in the mill at the moment. It's a tremendous chore, and how they can ever hope to keep up with it is beyond me. This isn't meant as a criticism; it's actually praise for their efforts. I just don't see how they keep up with the volume. But I don't believe it's coming at too fast a pace.

DR. NOBLE: Certainly we should constantly improve the channel-handling capacity, or the communication -handling capacity of the spectrum. And I don't believe we've moved too fast in narrowing the channels and in moving from what used to be a communications channel occupying in the order of about 160 kc, although licensed for 40 kc. When I started in the business, we used to swing far enough so that we covered about 160 kc for a 40 kc channel. Then we moved to alternate channel communications, where you could have a system set up on alternate channels without interference. The next stage was adjacent channel, and now we're splitting the channels. These are necessary steps in progress, and we can't move too fast. I think my position has been stated in my paper that we do need an objectively scientific re-evaluation of all the spectrum assignments. Not with the idea of a sudden upsetting change, but rather on the basis that plans should be established. Short, intermediate, and long-range plans should be established for the improvement in spectrum utilization and for the ultimate optimum use.

MR. JANSKY: There are many aspects to this question. I feel it's possible to go too fast in splitting channels. I think before we start to solve all these problems by merely creating more channels, we need to do some systems soul searching as to whether we are using the channels we now have efficiently. This is largely industry responsibility. The industry cannot expect the FCC to do its systems engineering for it.

COMMODORE WEBSTER: On behalf of the Conference Management, the audience, and myself, I wish to thank each member of the panel for taking time from busy schedules to participate in this afternoon's discussion. Our time, as usual with such affairs, has been all too short. We've just got started. However, it's been highly stimulating and very helpful in the course of solving the many vehicular communications problems.